National Air Brake Instruction Book

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National Air Brakes

MANUAL

OF

Installation & Maintenance

National Brake & Electric Co.

MILWAUKEE, U.S.A.

General Sales Office

519 First National Bank Building, Chicago, Ill.

National Air Brakes

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Preface

It is not exaggeration to say that no other invention in steam or electric railway engineering has contributed so largely to the safe operation of high speed cars as has the power or air brake in its present improved form. The hand-brake and mechanical friction brake have come and gone, being now regarded by all well-informed and experienced railway officials as wholly inadequate to the demands of modern electric railway operation.

The National air brake is the concrete embodiment of a gradual improvement extending over many years by the predecessors of the National Brake & Electric Company, the Christensen Engineering Company and the National Electric Company, who were the pioneers in the development of the air brake for electric traction service. In the few months that the National air brake apparatus has been on the market, it has met with such cordial approval that the most sanguine expectations of the Company have been exceeded.

In presenting this manual to the electric railway fraternity, the National Brake & Electric Company has been prompted by the numerous requests of its patrons for information in concise yet comprehensive form on the installation, operation and maintenance of the component parts of National air brake equipments.

In addition to this information it has been assumed that a brief discussion of the salient principles involved in the analysis of train operation with a view to the proper determination of car motor equipment and schedules would be appréciated by many electric railway officials. The matter on the plotting of train curves which is appended in the final pages, while very brief and elementary, covers the essential steps in this very important means of ascertaining the suitability of a given car motor for a given set of conditions as well as other desirable features of train operation.

The National Brake & Electric Company takes this opportunity to express its hearty thanks to patrons and friends, and trusts that it may merit their continued good will and patronage.

National Brake & Electric Co.
MILWAUKEE, U. S. A.

July 1, 1907

Manual of Air Brake Installation and Maintenance

Advantages of Air Brakes

All progressive railway companies recognize that the hand brake is not sufficient, and that the equipment of an electric car should include with the hand brake a reliable air brake.

The equipment of electric cars with straight air brakes makes it entirely safe and practicable to operate the rolling stock at much higher speeds and hence provide more frequent service without the first cost and maintenance expense which a slower schedule speed would necessitate. But what is perhaps of most importance to the electric railway manager is the great saving in power consumption which the use of straight air brakes assures. Numerous carefully conducted tests by the most progressive street railway companies have shown that a hand-braked car requires from ten to twenty per cent more power than an air-braked car. This greater economy of the power over the hand brake is due to the unavoidable practice of motormen who have only the hand brake to depend upon—of keeping the brake shoes "dragging" against the wheels so that they may be able to effect a quick stop in an emergency and have complete control of their car at all times. This action not only results in a rapid wearing out of brake shoes but also consumes power excessively.

The elimination of the disagreeable jars and shocks to the trucks and car body, which in the case of a hand-braked car frequently reduces its life one-third, is a most important feature of the straight air brake in reducing maintenance expenses. Among other advantages of the straight air brake is the prevention of "flat" wheels and the increased comfort to passengers; the retardation when brakes are applied is gradual and continuous and the release of the brakes is accomplished instantaneously and without shock.

Advantages of Straight Air Over Automatic Air for Ordinary Electric Railway Service

The matchless protection afforded by the automatic air brake system in steam railway practice has resulted in its universal adoption on steam operated lines and its remarkable success is by no means unmerited. However, the great popularity and reputation of automatic air in steam railway practice has created an impression in the minds of many persons, that automatic air is preferable to straight air for all electric railway practice. That this is a most erroneous opinion will be obvious upon second consideration.

The first and most important point of difference between steam and electric railway practice, is in the number of cars employed. In electric railway service short trains consisting either of a motor car or a motor car and one or two trailers utilized at close intervals, is becoming generally recognized as the only economical and successful method of giving the public good service—especially during "rush hours." In the development of surface and interurban electric railways, this method of operation will continue to be the most advantageous. Long trains will be an exception, therefore the straight air brake system will continue to be almost universal practice for the following reasons:

The air receiver in the straight air brake system consists of a single large reservoir charged to a high pressure. To operate the brakes the motorman turns the handle of the operating valve to such a position as will provide an unobstructed opening for compressed air to flow from the reservoir to the brake cylinder; thus as positive and reliable setting of the brakes as is possible is secured, combining maximum simplicity with absolute certainty. The velocity of air under high pressure is so great that the time elapsing before the pressure is equalized between the reservoir and brake cylinder on the last car of a train

of two or three cars, is so brief as to be practically instantaneous, giving as almost simultaneous application of brakes on all of the cars in the train as is possible with any system.

An advantage of highest importance possessed by the straight air system consists in the ability of the operator to increase or decrease the amount of pressure in the brake cylinder at will and with a fine degree of accuracy; whereas to decrease the pressure in the automatic system it is necessary to release the brakes entirely and re-apply them to the desired degree, unless the system is equipped with the graduated-release feature. This feature of the straight air system can be taken advantage of quite frequently when the car is coasting down long variable grades as well as when making a stop that must be accurately accomplished at a given point.

The incorporation of the emergency valve feature in the National straight air brake equipment combines as positive and reliable control with all the protection afforded by automatic air and with the additional advantages of few of the complications of the latter.

In the automatic air system there is an auxiliary reservoir in close proximity to the brake cylinder on each car. Between the brake cylinder and the auxiliary reservoir is placed a triple valve; all the triple valves on a train are connected to each other and to the motorman's valve on the motor car through the train line. The triple valve is operated by a reduction of pressure in the train line which is accomplished by moving the handle of the motorman's valve so as to open a port communication from the train-line to atmosphere. When the pressure in the train line is reduced six to eight pounds, the triple valve automatically operates, establishing an opening between the auxiliary reservoir and the brake cylinder. The triple valves on all cars in the train operate almost simultaneously and the compressed air has only to flow a short distance from the auxiliary reservoir to its particular brake cylinder.

On long trains such as become necessary in elevated railway practice with multiple unit method of control, the brakes on the last car are applied more quickly than would be the case with the straight air system. In a short train however, the time consumed in reducing the pressure in the train pipe and in operating the triple valves is fully as much as that required in the straight air system in supplying air from the main reservoir on the motor car to the brake cylinder on the last car of the train. This is readily proven by timing the application of brakes on cars equipped with both systems.

Therefore it cannot be claimed that the brakes in the short train can be applied any more quickly with the automatic than with the straight air system, and on single or two-car trains the advantages of the reliable and positive control afforded by the straight air system are greatly increased. Should a train of cars equipped with automatic air break-in-two the train pipe would also be broken and a reduction of air in the train pipe would occur which would cause the triple valve to operate and both sections of the train would be stopped; but the liability of a short train becoming parted as compared with a heavy train of many cars is reduced to a minimum and can still be further reduced by increased strength in hog chains and couplings, because it is much easier to provide a greater factor of safety in these details with two or three cars, than with six or eight. If, however, nothing more could be said against the automatic system for short trains, the above advantage would be worthy of consideration, but to counterbalance this advantage the National Emergency Valves are designed to eliminate the deficiencies of the straight air brake system by giving to it the automatic feature in the case of separation of the cars of a train and by putting the control of the brakes in the conductor as well as in the hands of the motorman. These valves give all the advantages of automatic air with but few of its complications. The emergency valve is mounted on the emergency valve bracket which may be

placed at any convenient place under the car body or if the bracket is not used it may be attached direct to the head of the brake cylinder and has connections with the main reservoir, the auxiliary reservoir, the train pipe line and an emergency pipe line, as well as with the brake cylinder. The emergency pipe line is continuous throughout the length of the train and takes the place of the customary equalizing pipe line employed to balance the pressures in the reservoirs of the separate cars.

The question thus resolves itself into the selection of the lesser of two complications and the conclusion must be determined by careful consideration as to whether failure of any one triple valve is more likely to occur than the parting of a short, light train equipped with heavy couplings and hog chains; and should be further influenced by whether the results in one case would be more likely to be disastrous than in the other. Nearly every electric railway engineer and superintendent of motive power agrees that the equiping of single cars with automatic air is not only folly but positively dangerous, and for two cars it is almost equally as bad. Much difference of opinion exists as to the exact length of the train on which it becomes an advantage to place automatic air devices, but there is no question that for trains of three cars or less, straight air is the safest, cheapest and most easily maintained.

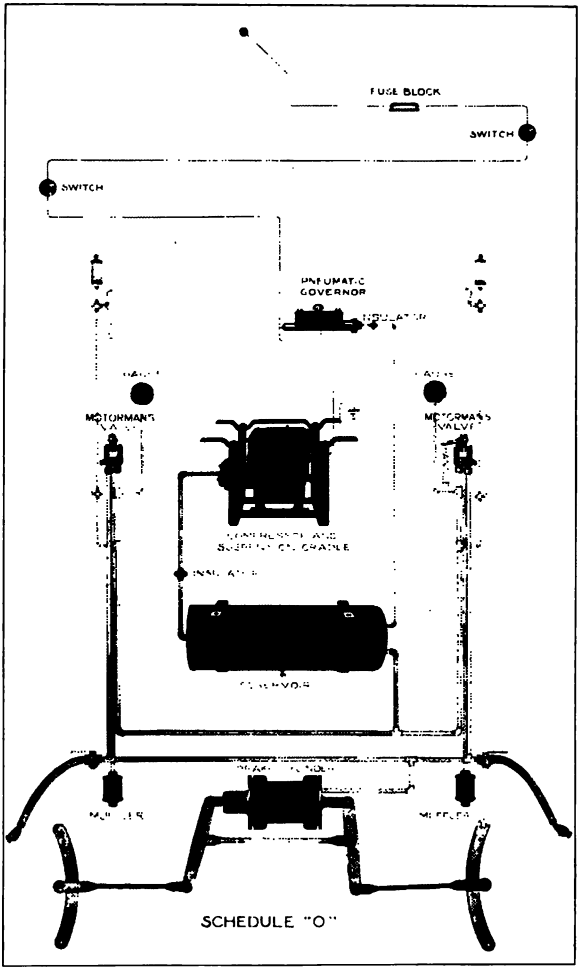


FIG. 1. National Straight Air Brake Equipment for Double End Electric Motor Car

The National Straight Air Traction Brake with Motor-Driven Compressor General Description

The National Straight Air Brake Equipment is made up of the following necessary devices: 1st—An Air Compressor driven by an independent electric motor and supplying the compressed air. 2nd—An Automatic Governor which stops and starts the air compressor, thereby maintaining the pressure and regulating the supply of compressed air. 3rd—A Main Reservoir in which the compressed air is stored. 4th—A Brake Cylinder with piston rod connected to the brake levers in such a manner that when compressed air is admitted into the brake cylinder by means of the motorman's operating valve, the piston is forced outward by the compressed air and the brake shoes applied against the wheels. 5th—A Motorman's Brake Valve placed at each controlling point of the car by means of which the compressed air is admitted from the main reservoir to the brake cylinder and from the brake cylinder to atmosphere. 6th—A specially constructed Piping System connecting the main reservoir with the motorman's brake valve and the pipe leading from this valve and extending throughout the entire length of the train; the latter is termed the Train Pipe and is fitted with flexible hose and couplings between the individual cars, with a stop cock at each end of every car and an auxiliary pipe leading to the brake cylinder arranged under each car. 7th—A System of Wiring including switches and fuse boxes which connects the main trolley circuit to the compressor and governor. 8th—The Hose Couplings with which each end of every car is equipped and by means of which the train pipes on the cars are connected to form a continuous train pipe line. 9th—An Air Gauge of the single hand type to indicate the pressure in the main reservoir only. An air gauge provided with two hands is sometimes employed, one of which indicates the pressure in the main reservoir

and the other the pressure in the train pipe, the former hand being colored red and the latter black. 10th—A Safety Valve to prevent possibility of over-charging the main reservoir and the piping system. 11th—Also frequently required is a Chime Whistle set operated by air pressure as a signal of warning instead of a gong or bell.

In plate 1 is shown the common arrangement of the apparatus and piping on a double truck electric car. Figure 2 is the diagramatic representation of the necessary parts of the brake system and their respective relations when a motor car and trailer are equipped.

Installation of Straight Air Brake Equipment

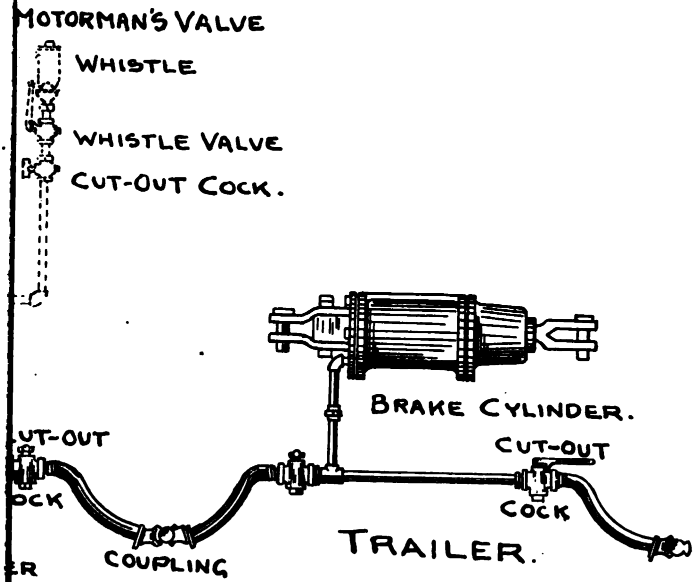
The relative arrangement of the parts which make up the National Straight Air Brake Equipment as shown in Figure 2, was decided upon after close study and many years experience; therefore the National Brake & Electric Company earnestly advises that the parts of this equipment be connected in the similar relative order as herein illustrated. The factors which govern the most desirable location for the compressor, reservoir and brake cylinder are: 1st—The existing electrical apparatus under the car and to be installed there; 2nd—the parts requiring care and inspection, should be mounted in the most accessible positions.

The location for the parts having been determined upon, it is recommended that the apparatus be installed in accordance with instructions given in the Instruction Chapters of this Hand Book, commencing on this page.

Instructions for Installing National Straight Air Brake Apparatus

Installation of the Motor Compressor

It has been found from long experience and experiments, that the most desirable place for the motor compressor is under the car body. On account of the


MOTORMAN'S VALVE
WHISTLE
WHISTLE VALVE
CUT-OUT COCK.
BRAKE CYLINDER.
UT-OUT
OCK
CUT-OUT
COCK
COUPLING
ER
TRAILER.

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thoroughly dust-proof and rain-proof construction of the A-1, A-4, BB-2, BB-4, CC-3 and DD-4 type compressors the standard air brake equipment does not include an enclosing box for the motor compressor. The use of such a device would be a superfluous precaution and in addition would hinder the circulation of air around the compressor cylinders resulting in a reduction of nearly 25 per cent in efficiency.

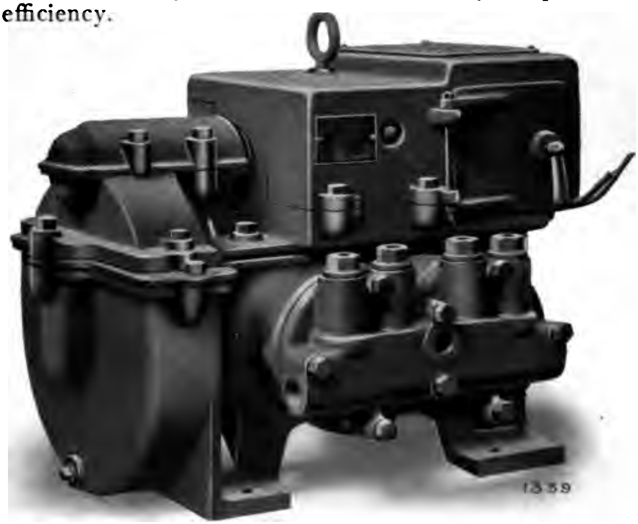

Fig. 3. "A-1," National Motor Compressor

There is furnished with each compressor, a light but highly rigid suspension cradle made of wrought iron bars. This cradle combines great strength with unusual compactness and quick accessibility to all parts of the compressor requiring attention when under the car. The suspension cradle comprises the cross-bars, hangers, tie bars and insulating pieces. The base of the compressor is bolted directly to the tie bars (1) which are insulated from the hangers (2) by fibre and hard wood insulation (3).

The above named parts comprise the cradle proper suspended from the crossbars (4) which in turn are bolted directly to the car body. The compressor being very strongly supported by the wooden blocks and crossbars, its vibrations are completely absorbed and hence no strains are caused on the car body. The compressor may be quickly removed from the suspension cradle by raising it about one-half inch and sliding out four bolts.

Selecting a Position for the Compressor

The selection of the most desirable position for the motor compressor under the car is largely governed by the amount of apparatus already there. The chosen place should be such as will ensure freedom from heated air from the resistance grids or car motors and such that all oil holes in the compressor pump base will be readily accessible from the street. The air supply can be piped from any convenient point in the vestibule or roof of the car. The suction pipe has at its extremity, a suction strainer filled with pulled, curled hair with a fine mesh screen over the opening. The method of installing is as follows:

The compressor should always be installed with its shaft crosswise of the car and with the gear inside or as near the center of the car as possible.

The base of the compressor should be securely fastened to the suspension cradle, taking care to tighten cap screws and nuts solidly. Then attach the crossbars firmly to the car framing at uniform and proper distances apart. If the under framing is not suitably arranged to conveniently receive the crossbars, secure one of the crossbars to a piece of the car framing and insert a suitable timber for the other. Eight $\frac{5}{8}$-inch bolts should be employed for each crossbar. Lag screws are not permissible for this purpose. It is permissible to bend up the ends of the crossbar and bolt them to the side of the sill. When the compressor must be removed from the cage it will be found that the construction of the cage is such that the

compressor will readily come through two sides of the cage without removing any part of it.

The vent openings in the side of the pump base are for the purpose of carrying away vapors that may be generated in it. These openings should never be closed or made smaller.

The connections to the main reservoir must all be made at the opposite end from that at which the dis-

FIG. 4. A-4 Compressor Mounted in Suspension Cradle

charge from the pump enters, to ensure passage of air through the reservoir and the deposition of water which may be precipitated in the cooling of compressed air; likewise any dirt or oil that may have been brought along with it.

In case a motor compressor is to be installed in a factory for various purposes, it may be either bolted to a stout frame set in a cement foundation, or it may be suspended in a substantial manner by means of the suspension cradle in a convenient and readily accessible place. It should be located where the air is cool, clean and dry and if this is not possible the suction valve should

be piped to the outside air. If possible the compressor should be suspended away from the ceiling, as heated air being lighter than cold air, ascends to a point near the ceiling. Care should be taken to insulate the compressor from ground; this is effectively done by using a base made of hard wood.

FIG. 5 Motor Complete

Looking at the motor compressor from the gear end, the pump shaft should rotate clock-wise and the motor shaft in the opposite direction. The direction of rotation of the armature may be changed by reversing the brush holder connection.

A card showing the arrangement and connections of the straight air brake equipment is attached to each compressor sent out and should be carefully studied. In connecting up the wiring of the compressor the positive wire of the circuit should be connected to the lead extend-

FIG. 6. Pump Base Complete

ing through the motor frame nearest the commutator door. Connect the other lead to the negative side of the circuit. The set screws on the brass terminals must be tightly set and the terminals completely wrapped with insulating tape.

FIG. 7. Compressor Dismantled Sufficiently to Permit Removal of Armature

While the directions for installing the compressor as herein given serve as a good guide, they should not be considered as ironclad rules. On account of the arrangement of the existing equipment differing so widely on different cars, and other conditions varying so markedly, the judgment of the master mechanic must be exercised in determining the method of installation. What might be good practice for a certain road might be altogether unsuited to a different road.

Inspection and Maintenance of National Straight Air Brake Apparatus

Motor Compressor

The air compressor and its driving motor require but nominal attention. The following are the most important points in their maintenance: (1) The oil is introduced into the pump chamber through oil holes or plugs which are arranged as shown in Figure 19.

A good quality of engine oil should be used, such as will suffer no change from the high temperatures sometimes reached in the crank chamber after long operation of the pump. The oil used should also have a low freezing point. The bad results obtained from the use of crude, unpurified oils in causing abrasion of the cylinders and losing body under high temperatures will greatly over-balance the low first cost obtained by this policy. Inspection should be made at least every other day and the oil supply regularly replenished once a week; oftener if necessary. About every two and a half months at the least, the drain plug (6) Figure 19, should be opened and the oil drained off for filtering. (2) The armature bearings should be regularly inspected and oiled when needed. The armature bearing on the commutator end is oiled through filling plug (46) and does not require any further attention except that the oil should be replenished when inspection shows this to be necessary. The bearing at the gear end should be oiled through filling plug provided for that purpose. This bearing requires no further replenishing after the pump has once been started, as the oil isconstantly replenished by the motion of the gear.

The armature is removed by taking out the cap screws (55) which fasten the field frame to the motor base; then disconnect the brush holder leads and the field coil leads, and after removing the brush holder unscrew the cap screws, which secure the top half of the motor bearing housing, take out cotter pins (53) after which pinion (74)

may be pulled off. It is necessary that the armature should be free to move in the opposite direction, as the gear teeth prevent the pinion from moving outwardly.

The armature may now be lifted from its position, much care being taken to prevent it from striking against pole pieces and injuring the cross connections at the end of the core.

In replacing the armature, slide it carefully into the fields until the threaded end projects from the bearing

FIG. 8. Lower Half of Motor

with the key-way upmost. The pinion should then be slid into position and a small lever used to force it into alignment with the shaft.

Replace the head with the commutator bearing, care being taken to keep grit and dirt out of the bearing and from the oil rings; and see that the oil rings are in their proper position on the shaft. The electrical connections should be made exactly as before and the brushes also replaced as original to preserve the same brush pressure on the commutator.

While the pinion is still uncovered, turn the armature by hand to determine whether the gears run freely; then

screw the bearing shell back into place and run the compressor with the motor long enough to pump full pressure in the reservoir. The arrangement of the suspension cradle is such that the disassembling and re-assembling may be easily done while the compressor is in position under the car and either operation can be done by one man who has had a short experience in this work and is provided with a standard wrench for this purpose.

(3) If the field coils must be removed the compressor should be taken from the car and since this operation is easily accomplished with the National type of suspension, when a suitable kind of jacking apparatus is provided in the pit, it is very advisable that roads using air brake equipments, keep several extra compressors on hand, so that a damaged one may be easily replaced and the repairs made in the shop during day hours which can be done to a better advantage than at night.

(4) The commutator should be kept clean, but not necessarily highly polished; a rich glossy bronze is most desirable. The brushes should always have a good contact, and also be free in their holders. The brush tension can be increased or decreased by means of the carbon adjustment. When it becomes necessary to turn down the commutator due to wear by the brushes or other causes, particular care should be taken to bevel off the corners slightly on the end of the bars. If the bars are left with a sharp edge, the mica is more likely to crumble away and cause a short circuit from bar to bar; the mica will then become carbonized and the commutator in time ruined. In removing the commutator, the oil guard which is shrunk on the shaft should first be taken off either by heating with a blow torch or by turning off on a lathe; the commutator can then be pulled off easily with screws in the usual way. A new oil guard must be shrunk on and finished like the old one.

(5) If for any reason the brush gear must be disassembled, especial care should be taken to have the brush lead as originally adjusted. This adjustment is

readily effected by screw (120). Ordinarily there will be no occasion for changing the brush adjustment as the entire motor can be taken apart without doing so since the brush holder yoke is attached to bearing cap (42) only. (6) When removing the pinion from the armature shaft, always use a pinion puller as shown in Fig. 14. Never use a sledge hammer for this purpose. (7) When removing the gear from the crank shaft, use a wooden mallet on the rough part of the gear; in such cases great care should be taken not to injure the teeth as they will only have to be repaired again before the compressor can be put in service. Since the tendency of the pinion is to wear the gear teeth at the two points corresponding to the

FIG. 9. Brush Gear Complete

FIG. 10. Brush Gear Disassembled

dead centers of the crank shaft, there are two key-ways 90° apart for turning the gear one-quarter. (8) If the suction and discharge valves wear irregularly, they as well as their chambers should be thoroughly cleaned in gasoline at least once every six months. The valves should be removed and their cavities thoroughly cleaned

with gasoline. *Never put any oil on the valves.* The suction strainer should be cleaned once every week when oiling to avoid the accumulation of dirt therein with consequent reduction of compressor efficiency. (9) In assembling the motor compressor, much care should be taken to have the gear and pinion mesh properly, since a defect in the meshing of the gear will result in a pounding or grinding noise when the compressor is operating. The best results are obtained by having a play of about one-sixty-fourth of an inch between the teeth.

FIG. 11. Piston, Rings and Connecting Rod

If a pounding develops in the compressor, remove the pump base cover and adjust the crank bearings of the connecting rods by taking out some of the washers provided for this purpose. The connecting rod caps are adjusted by means of these shims which, when removed one by one, draw the connecting rod caps into better bearing surface on the crank shaft. Be sure to tighten the lock nuts and replace the cotter pins.

To remove the piston packing rings or the wrist pin, the connecting rod must be detached from the crank shaft. After removing the cylinder head, the piston can be taken out.

Some care must be taken in replacing the packing rings as their diameters and faces are nicely ground. In replacing the piston rings they are first assembled in the groove on the piston with their springs; a flexible wire is then wound once around the piston ring. By pulling both ends of the wire the ring will be drawn to the diameter of the bore of the cylinder, which then makes it easier to push the piston back to its original position.

FIG. 12. Phantom View of Compressor Base Showing Third Bearing, Crank Shaft, etc.

In removing the wrist pin, take out the set screw and by gently tapping the small end of the wrist pin with a block and mallet the pin is easily removed.

(10) Insulation couplings should be kept tight and in perfect order; regular inspection of these parts is therefore necessary.

If the compressor is constantly blowing its fuse and the motor is working properly, it may be assumed that the fault is in the pump. Inspection will likely show

that the discharge valves are sticking or that the piston is operating with considerable friction in its cylinder, due to insufficient lubrication, or that a hot bearing exists. Under no circumstances should a heavier fuse be substituted for the size advised on a given compressor, as a burned out motor may result.

The sizes of fuses which are recommended for the different types of compressors, when operated on 550 volt currents, are as follows:

COMPRESSOR NUMBER	AMPERES OF FUSES AT 550 VOLTS
A-1	6
A-2	6
A-4	6
BB-2	10
BB-4	10
CC-3	15
DD-4	20

This Company declines all responsibility in repairing motor compressors in which no attention has been paid to lubrication or in which the above precautions are unheeded.

FIG. 13. BB-2 Type Compressor

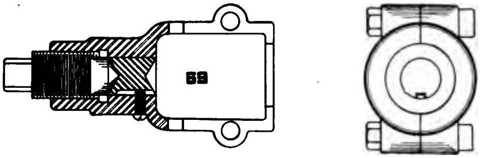

FIG. 14. Pinion Puller

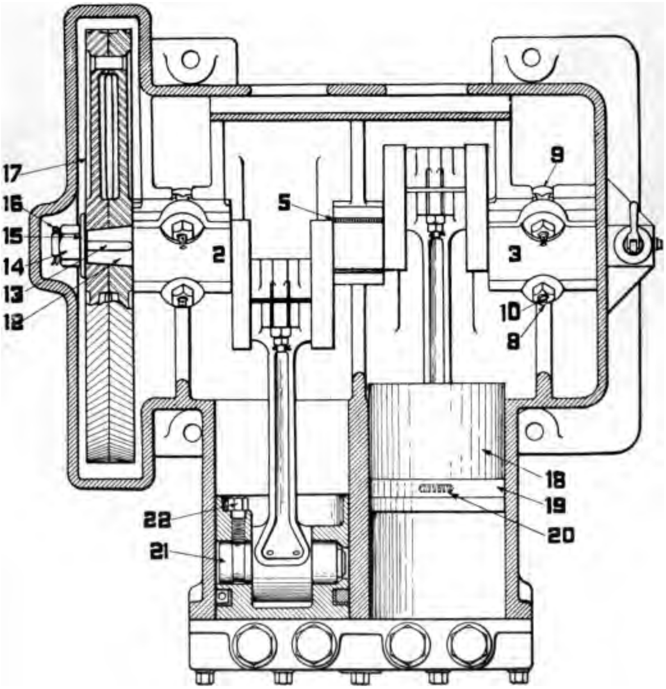

FIG. 15. Sectional Diagram of Compressor Base

Direct Current, Series Wound Motor Compressor Type A-4

In Figures 15 to 19 the construction of this type of compressor is clearly shown. The air is drawn into the cylinders by the suction valves (31). The end of the air intake pipe is fitted with straining screens filled with pulled, curled hair. The design of the mesh of these screens and the arrangement of the absorbent is such that all dust and foreign matter is thoroughly entrained before it reaches the cylinder. After being drawn in by the suction valves (31) the air flows through ports into the cylinders; on the return stroke air is forced through the discharge ports past the discharge valve; the air then issues to the discharge pipe. The suction and discharge valves are made of hard, cold drawn tubular steel and are easily accessible and removable. By unscrewing the valve caps (32) on top of the cylinder head all valves are quickly accessible. Since the valves are seated by gravity there are no springs to corrode or get out of temper. The complete trunk pistons (18) are fitted with carefully ground piston packing rings (19). When dismantling the pump, each ring should be used with the piston on which it was originally fitted. The piston wrist pins (21) on which the tail end of the connecting rods work, are of hardened, carefully ground steel and are held in place by the set screw (22); working on them is the bronze bushing (76) in the connecting rod (23). The lining of the crank under the connecting rod is a special quality babbitt and is hinged at its lower end and fastened by an eye bolt (26) at the upper end. The thin steel shims (27) are removable; as the bearing wears the strap may be tightened on the others and locked with a jam nut.

It is very essential that the shaft should rotate with the compression part of the stroke on the upper half of the revolution or in a clock-wise direction when viewed from the gear end. The crank shaft (12) is of special grade steel liberally proportioned with generous sized outside

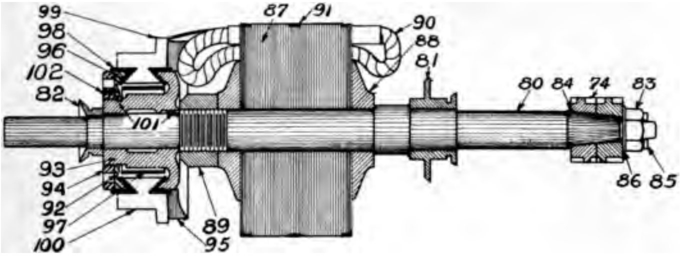

FIG. 16. Sectional Diagram of Compressor Armature

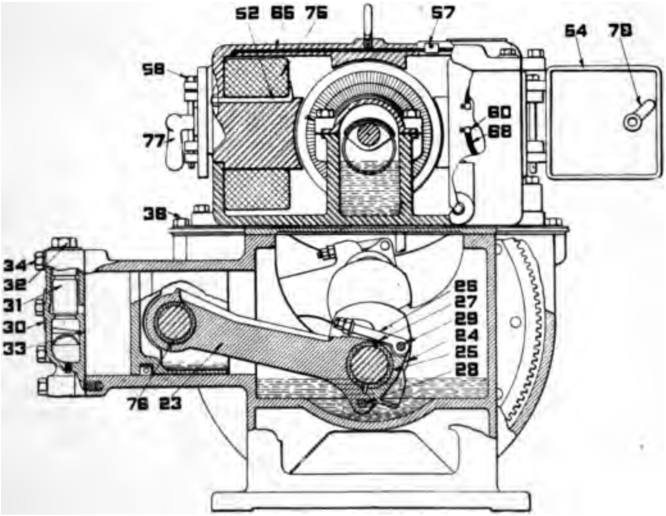

FIG. 17. Sectional Diagram of Compressor

caps (2) and (3) of lumen; bushings (4) and (5) run through the center.

The lubrication of all these parts is effected by a bath of oil with which the crank case is filled through the screw plug (6), which is fitted with a handle. The gear (17) on the overhanging end of the crank shaft is made of a special high carbon steel and is constructed in two halves which are solidly riveted together, constituting the very efficient herring bone type of gear. It is driven on to the shaft over a square key and rigidly fastened by a large nut.

The Motor

The motor is a four-pole enclosed series wound type provided with a cast steel housing (50) made in one piece and fitted with hinged doors over the commutator end which give quick access to the brushes and commutator. A hinged door (54) covers the opening snugly and thoroughly excludes rain and dust. Supports (41) at each end of the frame contain the armature bearings and are provided with oil wells so arranged that flooding the interior of the motor with oil is impossible.

The armature bearings (61) and (62) are amply dimensioned cast iron shells, lined with high grade lumen metal and fastened with dowel pins (44). Two oil rings are used on each bearing which gives positive assurance that the bearing will be lubricated as long as there is any oil in the well. An overflow pipe (47) at the pinion end of the armature bearing extends to the bottom of the crank case and absolutely prevents any of the gear oil which might escape from the pinion bearing, from flooding the motor.

The four field poles are a part of the frame (50) two being arranged in a horizontal plane to reduce the height of the compressor. The field coils are clamped in position by clamp bolts (52) provided with a nut.

The design and construction of the entire motor both mechanically and electrically, is made with the same high grade workmanship as is given all National apparatus.

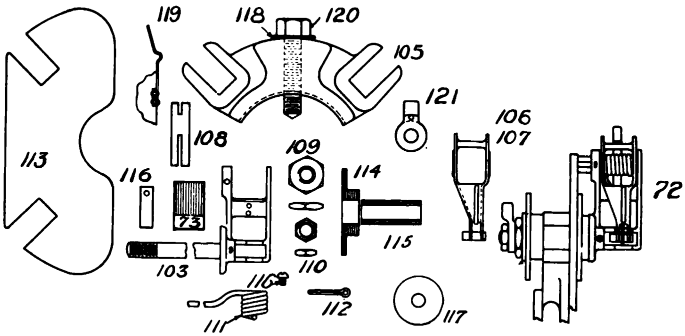

FIG. 18. Brush Holder and Parts

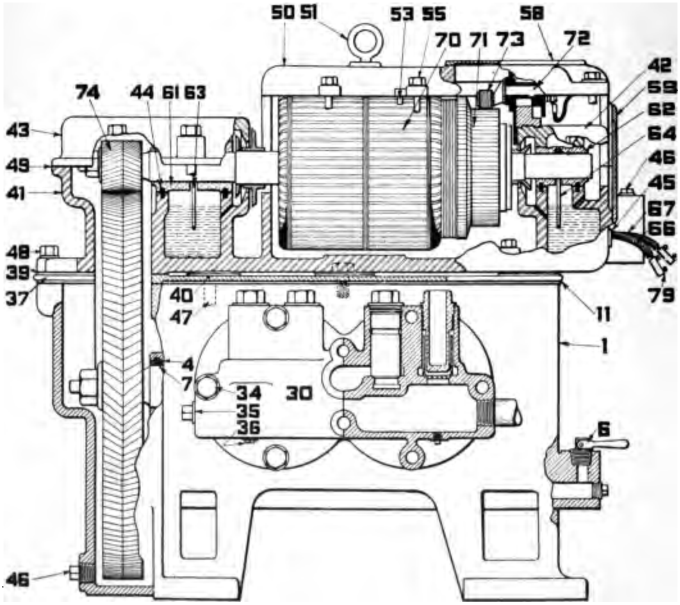

FIG. 19. Front Sectional Diagram of Compressor

The armature core is built up of soft, sheet steel laminations (87) with carefully punched slots in which are laid uniformly proportioned machine wound coils. The commutator bars (100) are deep and long and are amply insulated from each other by high grade mica segments (99). Much care is bestowed upon the support of the leads from the coils to the commutator bars. This support is a high grade insulating ring (95) resting on the commutator sleeve (93). The end portions of the coils are also banded with piano wire (91) over insulation tape to safe-guard them from damage due to centrifugal force. The two brush holders (72) are supported on the adjustable cast iron yoke (105); they are of cast brass and are held in place by the hexagonal nuts (109-110) and threaded in the body of the holder. The brush holders are well insulated from the yoke by a shield (113), cap screw (120) and washers (114) and (115). The carbon brushes (73) fit in machined guides and are maintained in contact with the commutator by coiled steel tension springs (111) which keep a uniform tension throughout the life of the brush.

As all these compressors are primarily intended for operating electric railway brakes, they must be operated intermittently and even then a limit is imposed upon the length of time they can be safely run, due to temperature rise in the motor. The maximum continuous run which it is advisable to operate them is shown by the following table:

PRESSURE	OPERATION	REST
130 Pounds	10 Minutes	20 Minutes
100 Pounds	15 Minutes	15 Minutes
65 Pounds	15 Minutes	15 Minutes
20 Pounds	25 Minutes	5 Minutes

This table will serve as a good basis for the operation of ordinary railway compressors in average commercial service, and shows the maximum continuous run which is recommended for compressors operating at various pressures and the interval of rest which is desirable.

Type "A-2" Compressor and Apparatus

The traffic conditions under which some electric railways operate do not require the use of heavy cars nor frequent braking applications, therefore it is quite possible in such cases to employ a smaller size of motor compressor than is usual for single car and intermittent trailer service, employing double truck cars.

FIG. 20. A-2 Compressor from Gear End

FOR USE ON SINGLE TRUCK CARS the National Brake & Electric Company has developed and manufactured a very compact and conveniently installed type of compressor termed the A-2 type which has a capacity of 11 cubic feet of free air per minute, and which is constructed of the same high grade materials and with the same care in workmanship as those of larger output.

The essential differences in design of the A-2 compressor over the A-4 and the various other types of larger capacity are a modified form of pump base and such an arrangement of the gear case as to greatly reduce the height of the compressor. The motor is of the open instead of the enclosed type which feature also contributes towards making it of lower height than the com-

FIG. 21. A-2 Compressor, Rear View from Commutator End

pressors of larger capacity. These alterations in design over standard types were made for the purpose of producing a compressor which could be readily and conveniently placed under a car seat with the governor.

The arrangement and sequence of the parts of an equipment in which the A-2 compressor is employed is clearly shown in Figure 22. The motor compressor (1)

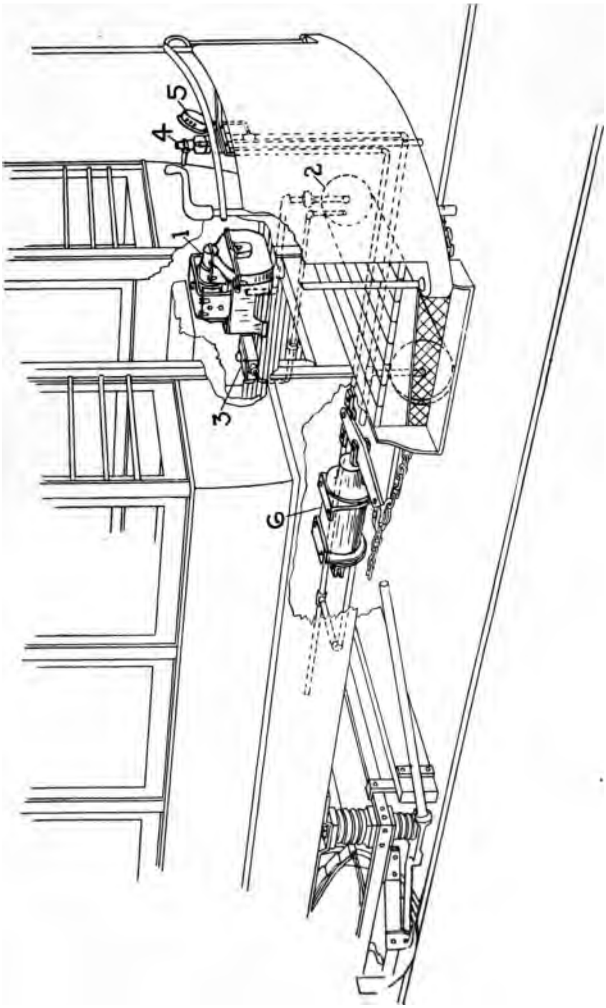

Fig. 22. Single Truck Car Equipment with A-2 Compressor

is located under the car seat near the door and almost directly over the reservoir (2). In this position the compressor is fully protected from dust, dirt and the weather and the motor therefore requires no enclosing case, which would be a detriment as it would prevent the free radiation of the heat which is generated by the motor, as well as interfere with the quick and easy inspection of the commutator, brushes and other parts. The governor (3) which is of the standard oil-pneumatic type, is located in close proximity to the compressor and immediately over the reservoir, its position being quite advantageous as the temperature of the air near the compressor is always closely uniform.

The motorman's valve (4) and the gauge (5) which are the standard National Types as described in following pages are arranged directly in the cab and take up very little space. The brake cylinder (6) is also of the standard type and placed in the usual position. The piping connections to the several parts of the equipment are shown in dotted outline and are self-explanatory.

For single truck cars this equipment is the most compact, simplest and easiest maintained of any extant and gives the same high factor of safety and efficiency of braking application which characterize all National apparatus.

The Selection of a Motor Compressor

The selection of the proper size of compressor requires serious consideration of the following important points: (1) For traction service the size of car governs the size of brake cylinder which, conjoined with the number of stops made in a given length of time, will determine the amount of air used. The selection of the compressor should be made for conditions demanding the most frequent stops. (2) A motor car pulling trailers requires a considerable reserve in pump capacity in proportion to the number of trailers hauled, the size of brake cylinders employed, the number of stops and the size of the train pipe line. (3) The capacity of compressor required for a stationary or portable outfit can be readily calculated from the service in which it is used and a compressor of the maximum capacity of that amount selected. (4) Air whistle outfits need a reserve capacity in proportion to the size of whistle and the frequency of its use.

It should be carefully borne in mind that it is short-sighted economy to select a compressor with barely sufficient capacity to do its work, because the increased effort demanded to produce the necessary output will result in over heating, lower efficiency and not infequently expensive injury.

In selecting the most suitable size of motor compressor for air brake service an approximate estimate should be made of the amount of air consumed in a given average run of one hour. This determination should include the amount of air wasted by partial applications of the brakes as well as the air consumed by auxiliary pneumatic devices such as whistles, air signal systems, or door opening appliances when such are used.

The size of brake cylinder being determined from the weight of car, the quantity of air required for a braking application can be computed from the size of the brake cylinder, the area and the length of piston stroke; the average number of braking applications for the fairly

definite operating conditions multiplied by the air volume of the brake cylinder in cubic feet, will give the total amount of air which the compressor must supply. The

FIG. 23. National A-4 Motor Compressor

percentage of the time which a given compressor must operate to supply this quantity of air can then be readily calculated.

The following calculation illustrates this: the volume of an 8-inch cylinder assuming an average piston travel of eight inches is .23 cubic feet. Before the brakes are applied the piston is against the pressure head of the

cylinder so that when the piston has traveled eight inches, .23 cubic feet of air has been supplied to cause an equalization of the pressure inside the cylinder with that outside. An increase of this to 60 pounds gauge pressure requires 60÷14.7, approximately 4.1 volumes of free air extra or a total of 1+4.1=5.1 volumes, which equals .23×5.1=1.18 cubic feet of free air approximately. Hence five applications of the brakes with a cylinder pressure of 60 pounds requires about six cubic feet of free air. Hence the volume of the reservoir should be sufficiently large so that the withdrawal of six cubic feet of free air will not reduce the pressure over 12 pounds.

This quantity of free air (6 cubic feet) under a gauge pressure of 70 pounds equals (70+14.7÷14.7) 5.7 atmospheres which would be diminished by (6÷5.7) 1.04 cubic feet. A reduction of 12 pounds reservoir pressure is equivalent to the consumption of $\left(\frac{12}{70+14.7}\right)$ .14 of the initial capacity. The quantity by which the reservoir capacity is reduced by six applications of the brakes must be .14 of the original volume, or 1.04÷.14=7.4 cubic feet. That is if a reservoir pressure of 70 pounds is adopted the capacity of the reservoir should be 7.4 cubic feet.

It is of course, impossible to draw up rules governing the selection of a compressor. Traffic conditions differ so widely in different cities and the separate runs made by a car during a day's service frequently show such marked variations in the number of braking applications that predeterminations of the size of compressor which will take care of the maximum possible braking applications require to be made for each individual operating condition. The difficulty of giving definite instructions as to the proper selection of a compressor is also increased by the fact that the operating characteristics of motormen differ greatly—very rarely will any two motormen obtain closely similar results in the consumption of power and air in running the same car.

It cannot be too strongly urged upon street railway

officials that the comparatively small extra cost of a compressor with a capacity a few cubic feet higher than is absolutely necessary to operate the brakes on a given car under a given set of conditions, will result in greater economies in the long run. Thus if the operating conditions in a given city dictate the use of a compressor with 16 cubic feet capacity, the selection of a 20-foot machine would more than compensate for its extra cost on account of decreased cost of maintenance and longer life.

No motor driven compressor should be operated more than one-half of the total time a car is in operation.

If a compressor with a reasonable margin in reservoir capacity has been selected and if the apparatus and piping is in good condition, the actual running time of a compressor should not exceed 35 per cent of the total time even for cars in city service.

A prominent authority on air-brakes, Mr. E. H. Dewson, states that "the proper basis for the determination of the size of compressor to be supplied for a given brake service is that when the equipment is new, the required amount of air can be supplied with the compressor operating one-fourth of the time. This gives a safe margin to cover the decrease in efficiency due to natural wear, also the temporary derangements of the system calling for an increased supply until repairs can be made, or excessive demands due also to temporary causes. Thus, during the life of a compressor, the time it was running would average somewhat less than one-third of the total time the car was on the road."

Method of Making Competitive Tests of Capacity, Power Consumption and Efficiency of Motor-Driven Compressors for Brake Service. Edward H. Dewson, Street Railway Journal, February 27, 1904.

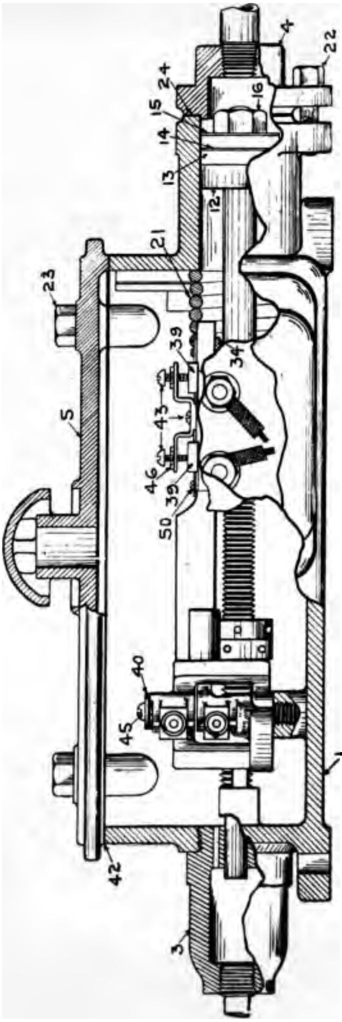

Fig. 24. Detail Assembly Type "N" Governor

Construction of Type "N" Oil-Pneumatic Governor

Referring to the sectional view of the governor (1) is the complete base of containing case into which are cast the keyways for fastening the forward end of the extension spring (21) and the contact arm stops. The containing case is fitted with a paper gasket (42) and the cover (5) and is screwed to lugs by means of screws (23). The piston (12) is equipped with double cups or gaskets (24) made of a special composition material which is not affected by oil. The cylinder head (4) is screwed in position by screws (22). The piston (12) works in the air chamber guided by (3) on the opposite end of the piston rod which is securely screwed to base (1). The piston (12) with the packing rings (13) is held in position by a screw (16). The packing rings (13) are of a special design which allow no escape of air around the sides of the piston but at the same time permit the piston to move freely in the cylinder. (14) and (15) are piston followers. The piston rod carries the operating spring (21) and a spring adjusting yoke or collar (19) at its forward end to which the controlling spring is secured. The adjusting yoke is provided with a washer (20) the tension of the spring being adjusted by turning the hexagonal nut (19). The cylinder end of the spring is held in the containing box by the two keyways referred to above. These keys are shaped in such a way that the spring is held very rigidly; this makes a neat, substantial and strong method of supporting the spring.

The cylinder head is tapped directly to the reservoir so that the piston is always subjected to reservoir pressure and no waste of air can occur. The spring used is of large diameter and made of special heavy wire carefully tempered, and will withstand any strains likely to occur without becoming weakened. The piston rod is threaded at its lower end to receive the adjusting nuts (17) for varying the range between minimum and maximum

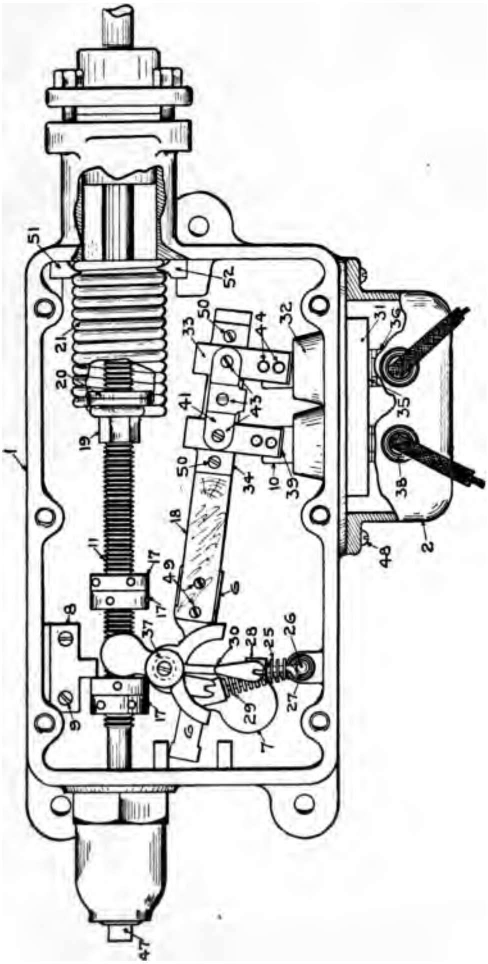

FIG. 25. Detail Assembly of Type "N" Governor

pressures. Double nuts are used so that by holding one and screwing the other the pressure between the two securely locks them together. These adjusting nuts are made round instead of square and are adjusted by means of a spanner wrench which militates against the temptation of a motorman with a monkey wrench, to tamper with the adjustment which the master mechanic has made.

A trip hammer of the "kodak shutter" type and made of brass, is pivoted on a post (37) between the adjusting nuts, its function being to trip the switch arm to open and close the electric circuit. The trip hammer mechanism which actuates the switch arm is accelerated by the action of the spring (29) supported on a pin (25) and fastened at one end by means of the pin guide (30) secured at the trip hammer end by means of a movable metallic block or eccentric device working between parallel jaws cast as an integral part of the trip hammer. The other end is secured to the wall of the containing case by means of toggle pin (26) which fits in lugs cast into the governor case. A smaller, shorter spring (28) of one-eighth the power of the trip hammer accelerating spring and separated by distance piece (27) from the former, prevents vibration of the switch arm when the circuit is open. The method of supporting this spring is identical with that of the accelerating spring.

The switch arm (18) is made of a special insulating material which experience has proven to be the most effective and durable insulating material for air brake service, especially high tension brake work. Being always under oil, no deterioration of the insulating material can occur. The motion of the switch arm in either direction is limited by two stops cast into the end of the governor case.

The moving switch blade contacts (39) are of heavy square shaped phosphor bronze and are adjusted by means of screws (43) and adjusting plate (41) so that the area of "wiping contact" may be increased or decreased as may be required. The stationary electric contacts (10) are heavy square shaped plugs, and are insulated from

the governor containing case by means of the heavy insulating bushings (32). Short circuiting between stationary contacts and case is therefore impossible. The arrangement of the supporting screws for the stationary contacts is such that they can be easily turned over to present a new contact for the switch blade if the occasion should ever arise, which will be rare.

The two terminals for the electrical connections are placed on the side of the governor case and are thoroughly insulated from each other by means of a thick fibre block

FIG. 26. Type "N" Governor

(31) which eliminates all danger of short circuiting. The two terminals can be either trolley or motor connection, respectively, without in any way affecting the operation of the governor, hence there is no possibility of making a wrong connection, a feature not possessed by any other governor. The terminals are protected from interference and danger of contact by means of the rectangular metal cover (2) screwed to the governor case. The leads from the motor circuit are run through insulated holes made either in the top or the bottom of this cover.

Instructions for Installing Type "N" Oil Pneumatic Governor

For traction service the governor is designed to be bolted to blocks on the floor of the car by means of the lugs on the case. A very desirable and practicable position for the governor is under a car seat inside the car, as directly over the reservoir as possible. This latter position assures greater uniformity in temperature than if the governor were placed elsewhere. For stationary service

FIG. 27. Governor with Cover Removed, Showing Details and Simplicity of Construction

it may be placed in any desirable position, except in a vertical position. Connect the governor as directly to the reservoir as possible so that pulsations in the air pressure on account of the operation of the compressor, or a drop of pressure in the pipe leading from the reservoir may be avoided as much as possible. The connecting pipe should be as short as possible; should have a downward slope towards the reservoir and be free from pockets where moisture might collect and freeze. For service in stationary plants where it is placed in a warm position such that moisture, which may be carried into the governor cylinder, will not freeze and thus cause

sticking of the governor piston; the relative location of the governor is not of much importance but when the governor is installed in a position where the temperature is liable to go below freezing, it should be placed so that moisture may drain out of the governor cylinder.

The electric terminals can be either trolley or motor connection, respectively, without affecting the operation of the governor. See that the terminals are in good condition and that the electrical circuit is continuous before putting the cover in position.

The governor case should be filled to within one-quarter of an inch of the top with any good quality mineral oil free from carbon, fishy or other organic matter. The oil should have a high flash test and a low freezing point. DO NOT USE KEROSENE OR ANIMAL OIL. Screw the cover down tight before putting the governor in service.

Maintenance of the Automatic Governor

The standard type N Oil Pneumatic Governor is such a simple and durable appliance that its maintenance is a matter of little trouble after it is properly adjusted. Tinkering or experimenting with it are the chief precautions to be observed. The only parts likely to require attention are the adjustment of the switch blade contacts to give an increased "wiping" contact after the stationary contacts have become slightly worn. A spring shoe device on each blade fitted with screws, enables the blades to be raised or lowered. Tightening the screws forces down the U shaped spring thus drawing the switch blades against the stationary contacts. Examination should be made of the contacts about once every three months to determine if it is necessary to increase the tension of the moving, against the stationary contacts.

The pressure at which the governor cuts in is regulated by the extension spring which is adjusted for the desired pressure by screwing the hexagonal spring nuts on the spindle. Screwing the nuts forward on the spindle

increases the tension of the spring and a higher pressure is required for actuating the governor. By moving the nuts towards the piston the tension of the spring is decreased and smaller pressure on the piston will cut in the switch arm.

As the pressure approaches a maximum the two nuts (17) on the piston side of the toggle regulate the range of its movement. The two corresponding nuts on the opposite side of the toggle also limit its movement as the pressure approaches a minimum. These two sets of double

FIG. 28. Governor Disassembled

nuts are merely two points for varying the time limit and range between which maximum and minimum pressures will be attained.

When it is necessary to change the adjustment of the governor, much care should be taken to prevent any organic matter from getting in the containing case, as it might cause some of the oil to carbonize and interfere with the satisfactory operation of the governor.

About once every six months the oil should be thoroughly filtered to remove any foreign matter which may have been introduced by removal of the cover. After an inspection or adjustment of the governor, much care should be exercised to replace the gasket properly and the cover should be screwed down tightly.

The inside of the cylinder should be cleaned about every three months and the piston rings softened by means of a light body oil or grease.

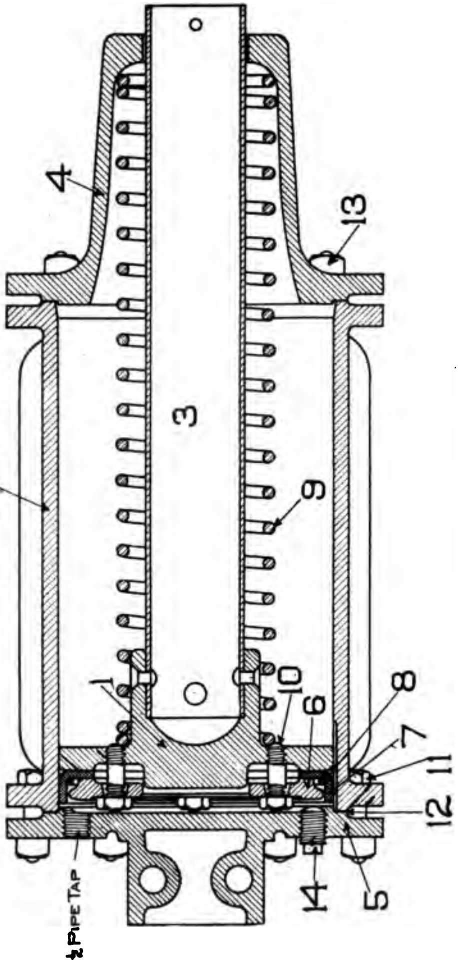

Fig. 29. Diagram of Brake Cylinder

The Brake Cylinder

The brake cylinder is provided with a hollow rod and a loose push rod and cross head which makes it possible to apply the hand brake without moving the piston, thus avoiding unnecessary wear and useless expenditure of force. Referring to the illustration, Figure 29, (2) is the brake cylinder, (3) is the piston and sleeve in which the push rod connected with a system of brake levers, is inserted; (4) is the non-pressure cylinder head, (5) is the pressure head in which are two ½-inch pipe tapped holes to one of which the air piping is connected, the other being closed by a plug (14). The pressure head is bolted to the cylinder by bolts (11) and the joints are made air tight by the use of a rubber gasket (12). The piston follower plate (6) clamps the packing leather to the piston by means of studs and nuts (10). The packing leather (7) is pressed against the cylinder wall to prevent air escaping past the piston. A round spring packing expander (8) serves to hold the flange of the packing leather against the walls of the cylinder.

A plain pressure head is generally provided, which is fitted with a detachable lever bracket so that the slack adjuster may be used or not, as desired; or the slack adjuster may be put on at any time without requiring a new cylinder head or any change other than removing the detachable bracket and putting the slack adjuster in its place. Unless specified differently, the plain head with slack adjuster lug is furnished.

Installation of the Brake Cylinder

If the brake cylinder is 10 inches or less in diameter, it should be bolted to a hard wood plank not less than 2½ inches thick and 12 inches wide and long enough to fasten it securely to the car body framing. Bolts smaller than ¾-inch should not be used for 10-inch and 12-inch brake cylinders, nor smaller than ⅞-inch for the 14-inch brake cylinder; and the plank support should be of propor-

tionally increased strength. The position for the brake cylinder should be so selected in its relation to the foundation brake rigging, that a release of brakes will force the push rod to the bottom of the hollow piston sleeve. It is advisable to place a union in the pipe connecting it to the train pipe, at a convenient point on one side of the cylinder, to enable the head to be removed for cleaning the cylinder.

In removing the cylinder head for cleaning, the piston should first be forced outward by a slight application and a nail or piece of wire inserted in the hole provided for that purpose in the piston rod pipe, to prevent the spring from forcing the piston out when the cylinder head is removed.

Inspection and Maintenance of the Brake Cylinder

All lint and other matter which might possibly collect should be scrupulously cleaned from the piston and cylinder, and caked up deposits of oil and grit should be carefully cleaned out of the leakage groove. The packing leather expander ring and piston should also be thoroughly cleaned. The packing leather should be kept soft and pliable so that it will have a tight fit with easy action in the cylinder; to this end a space between the leather and the follower should be filled with a light grease. The use of a light grease in the cylinder has been found to give better results than oil. The use of too much grease should be avoided as it tends to thicken and interfere with the easy working of all parts. The follower nuts should be frequently tested for looseness.

The Committee on Recommended Practice of the American Air-Brake Association (13th Annual Convention, June, 1906) advises that brake cylinders be cleaned and cared for as follows: (1) The brake cylinder need not be removed from the car for cleaning; first, secure the piston rod firmly to the cylinder head, then after removing the cylinder head, piston rod, piston head and release

spring, scrape off all deposits of gum and dirt with a narrow putty knife or its equivalent and have the removed parts wiped with waste saturated with kerosene or other light oil. (2) The packing leather should never be permitted to soak in kerosene oil as the penetrating qualities of kerosene reach into the pores of the leather and force out the life-giving qualities of the special oil with which the leather is treated by the manufacturer. (5) The expander ring to be of a circumference which shall fit the bore of the brake cylinder when the ring is removed from its place between the follower and packing leather and entered in the cylinder. (8) A goodly quantity of grease should be placed on the expander ring and the adjacent side of the packing leather, thus permitting the pressure to force the grease into the leather and giving it greater life. (9) No sharp tool to be used in getting the packing leather into the cylinder. (10) After the piston is in place, and before the cylinder head is fastened on, the piston rod should be slightly rotated in all directions about three inches from the center line of the cylinder in order to be certain that the expanding ring is not out of place.

The Reservoir

The reservoir is the receptacle in which the compressed air is stored. It should have a capacity sufficient to supply the air necessary for three or four applications of the brakes without a reduction of more than twelve or fifteen pounds in the reservoir pressure. It is also of considerable importance to have a reservoir as large as possible on the car as this will result in considerable saving in the cost of maintenance of the motor compressor. Too small a reservoir will cause every ordinary application of the brakes to start the compressor into action. Such constant starting and stopping will result in unnecessary wear to both compressor and automatic governor.

The weight of the car determines the size of brake cylinder to be used which in turn governs to a large extent

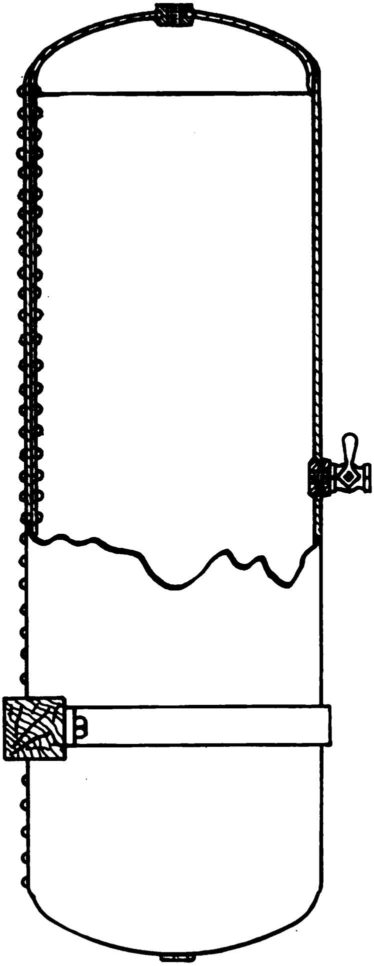

FIG. 30 Reservoir

the capacity of the reservoir. The use of the following sizes of reservoirs is recommended, the dimensions given being over-all:

For 8″ cylinder.................16″ x 45″
For 10″ cylinder.................16″ x 48″
For 12″ cylinder.................16″ x 60″

While the above sizes of reservoirs are considered standard, other sizes can be furnished when required.

Since the function of the reservoir is also to entrap any water, oil, or dirt which may be swept in by the compressed air thus preventing it being carried further into the brake system, it should be drained every day. The drain cock should be left open while the car is in the barn so that every trace of oil and water may be removed from the air storage space.

The reservoir is constructed of highest grade ¼-inch steel tubing designed to afford the maximum strength with a minimum weight.

The shell of the reservoir is made in one piece with overlapping seams which are firmly riveted together and rendered perfectly air tight. The ends of the reservoir are pressed in and beaded over to form a joint which is afterwards made absolutely tight by brazing.

At one end the reservoirs are tapped to receive the pipe connections to the compressor. They are tapped at the other end for the reception of the main reservoir pipe leading to the motorman's valve. A tapped hole is also provided for the connection to the air compressor governor. The points where these pipes enter are heavily re-inforced.

Installation of the Reservoir

The main reservoir should be well secured directly to the car body by means of the Reservoir Cradle which consists of U-shaped iron bars and hardwood cleats, which are bolted to the car body beams, either with long screws or through bolts. The cleat or plank is hollowed out so as to fit the curvature of the reservoir properly; the drain cock should always be placed downwards.

Air Gauges

On straight air brake equipments the single hand gauge which indicates the pressure in the main reservoir only, is standard practice. It is not only much cheaper than the duplex type gauge, but since an experienced motorman does not set the brakes according to gauge pressure but depends on his judgment, the use of duplex gauges is not essential. The case of the pressure gauge is five inches in diameter with a thickness of 2½ inches, and is constructed of a heavy brass casting, highly finished. A duplex gauge can be supplied on special order, either the plain duplex type or of the illuminated dial pattern.

Installation of Air Gauges

The pressure gauges should be placed within convenient sight of the motorman. The exact location is determined in each particular case by local conditions. In many cases the gauge is arranged overhead in the roof of the platform and above the motorman's brake valve. The single hand gauge which is most frequently used, is always connected to the main reservoir pipe. The use of one-quarter inch standard iron pipe is advised for connecting the gauges, although one-eighth inch pipe may be used; special fittings are required for the one-quarter inch openings at the gauge. This difficulty can easily be avoided by using a one-quarter by one-eighth inch coupling. The pipe connection to the gauge is usually taken from a tee just below the motorman's valve.

The duplex gauge is provided with two standard ¼-inch nipples for attaching to the main reservoir pipe and train pipe, respectively, with a corresponding red hand for main reservoir and black hand for train pipe. In case illuminated gauges are used the pipe connections are the same as above described, but a wire connection is made to the lamps of the gauge which are usually

FIG. 31. Air Gauge

connected in series with five of the standard 110-volt lamps on a car where 550 volts are used.

Classification of Piping

The Reservoir Pipe connects the reservoir with the motorman's valve and is also constantly subject to reservoir pressure. It is advisable to put cut-out cocks in this pipe at such points as are convenient of access, by means of which the reservoir may be cut off from the operating valve whenever it is necessary to examine or remove the latter. Generally the pipe connection for the main reservoir is one-half inch, being only a continuation of the supply pipe.

The Train Pipe runs from the motorman's valve to the brake cylinder. When trailer cars are used, a cut-out cock with flexible coupling is used at each end of the car so that the admission of reservoir pressure to train pipe will send air to both motor car and trailer brake cylinders. Ordinarily the train pipe connections are one-half inch,

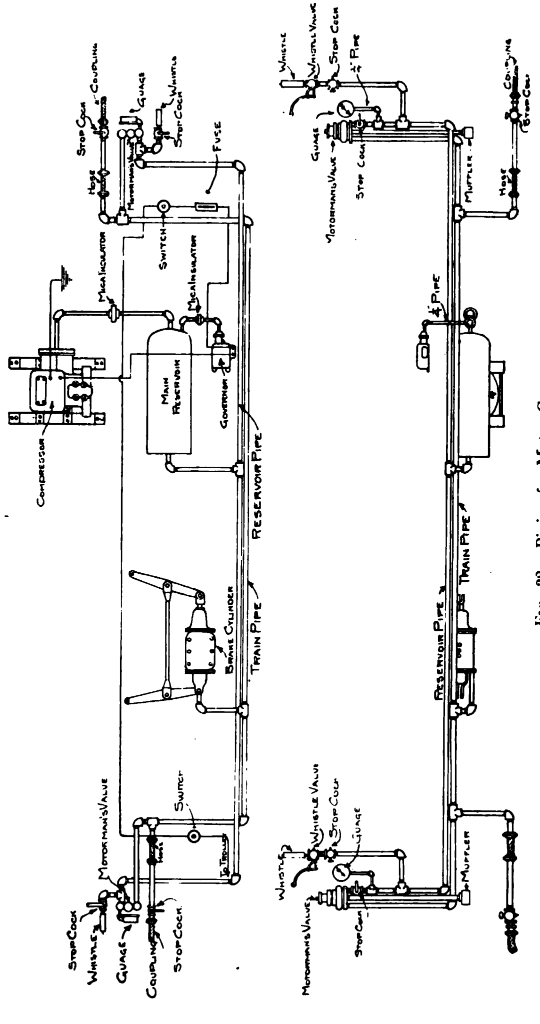

Fig. 32. Piping for Motor Car

for service where a number of trailers are used, the piping should be three-quarter inch or one inch in diameter.

The Reservoir Pipe connects the discharge opening of the compressor to the reservoir and is always subject to the reservoir pressure. The pipe connection from the compressor to the main reservoir is three-quarter inch for the A-1, A-2 and A-4 compressors, and one inch for BB-2, BB-4, CC-3 and DD-4, and is provided with insulation joint and union. The insulating joint should be located as close as possible to the reservoir and should be placed in as nearly vertical position as possible, and at the opposite end of the reservoir to the pipes leading to motorman's valve and governor.

The Governor Pipe connects the main reservoir to the automatic governor. Use one-quarter inch standard pipe for governor connection except where several trailers are employed when one-half inch pipe should be used. An insulating joint is inserted in the pipe near the governor which completely insulates the governor from any of the pipe which might become grounded.

The Gauge Pipe may be either one-quarter or one-eighth inch and should be chosen to suit the particular local conditions.

Installation of Piping

Long bends should be used wherever possible instead of elbows to avoid friction losses. When bends must be made the piping should be thoroughly blown out with steam or compressed air before the pipe is put in service. All joints should be threaded with sharp dies and the joint made tight with a good grade of shellac or japanned bronze applied to the male thread only, never inside of the fittings. Tinning in molten solder may also be used. With proper care a bottle tight joint is easily made.

After connecting up all piping full pressure should be pumped up in the reservoir with the motorman's valve at "release" position. All piping should be blown out

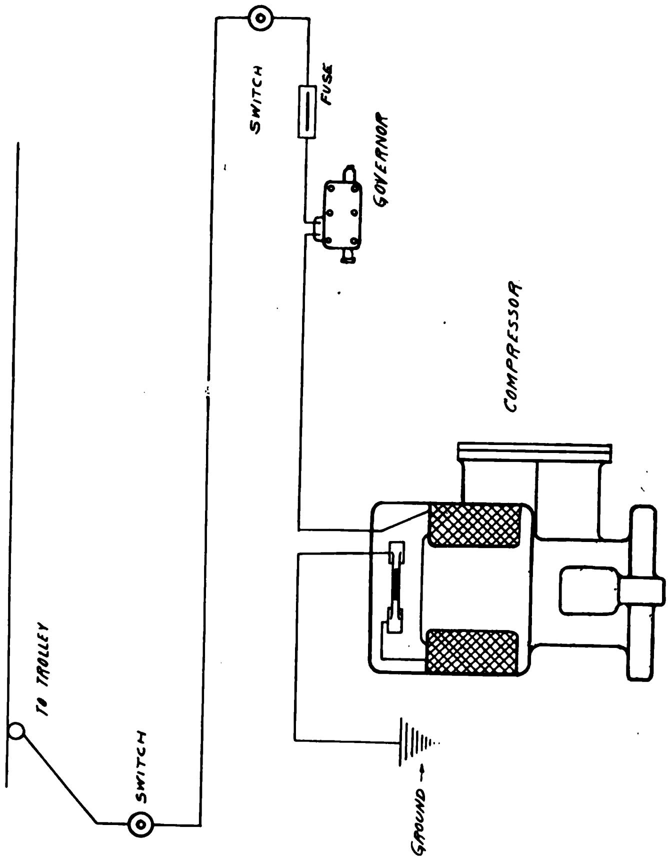

Fig. 33. Wiring Diagram

after which maximum pressure should be pumped up in the reservoir and tests made for leaks at the joints and cut-out cocks. This may be done by applying soap suds. When all leaks have been stopped, the piping should be so arranged that there will be no sags or pockets wherein moisture might collect, freeze and cause trouble. The piping should then be firmly clamped to the car to prevent vibration which might spring leaks.

Installation of Hose Couplings

It is well to provide a dummy coupling at the end of the car easily accessible to the hose coupling which should be coupled to the latter when the end of the train is disconnected. This will avoid the blowing of dust and dirt into the train line.

Wiring for Motor Compressor Outfits

The wiring connecting the main trolley circuit with the motor compressor should be installed in as high grade first-class manner as possible with special precautions to avoid the possibility of grounds developing after the car has been in service for a time. This wiring should be connected to the trolley wire at a point just inside of the lightning arrester. As far as practicable wiring should be run inside of the car, substantially cleated in place and should always be so located that there will be no danger of injuring it when the car is being jacked up.

Where the wiring is exposed underneath the car or runs over iron, it should be covered with a good rubber tubing. The size of solid rubber covered wire used should be No. 12 B & S for A-1, A-2 and A-4 compressors and No. 10 B & S for BB-2, BB-4, CC-3 and DD-4 compressors when operating on standard railway voltages. Although smaller sizes of wire may be used without causing prohibitive heating or heavy drops, they are however, too weak mechanically.

While the relative arrangement of the various parts of the equipment are fully shown in the diagram (Plate 33), the position at which the compressor circuit is to be connected to the trolley line must be decided on in each individual case. If the connection is made to the trolley line outside of the main switches, many advantages result such as for instance, preserving the electrical continuity of the compressor circuit should blowing of the main fuse occur, and current may be had in the compressor circuit when it is not desired on the controller. If connection for the motor compressor is made between the first main switch and the point where the light circuit is connected a very effective lightning arrester is made when the lamps are turned on during an electric storm, but a special arrester for the motor circuit will compensate for its slight extra cost as a protection to the compressor.

The compressor switches should be located within convenient reach of the motorman without requiring him to move out of his normal position. The partial enclosure of main switch under a shelter is recommended as a protection against rain, meddling by passengers or becoming caught by the trolley rope.

The main switches are single pole, double break, snap switches of the indicating type "On and Off," which slide behind a screen on the front of the cover and show whether the circuit is made or broken.

Fuse Block

The fuse block or base is made of a special grade porcelain and may be placed in a convenient and accessible point between the main switch and the governor It should be easily accessible with a screw driver; the point selected should also be dry and free from any danger of ground connections.

The fuse supplied is of the non-arcing type fitted with a small wire on the outside to indicate whether the fuse has blown or not. The fuse block is provided with bayonet clips so that the fuse proper may be readily placed in position.

FIG. 34. Snap Switch

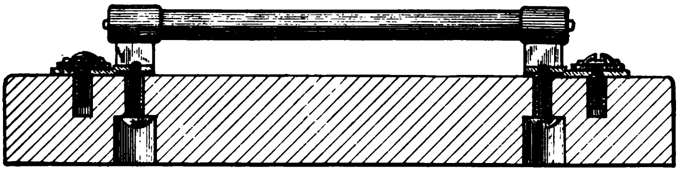

FIG. 35. Fuse and Base

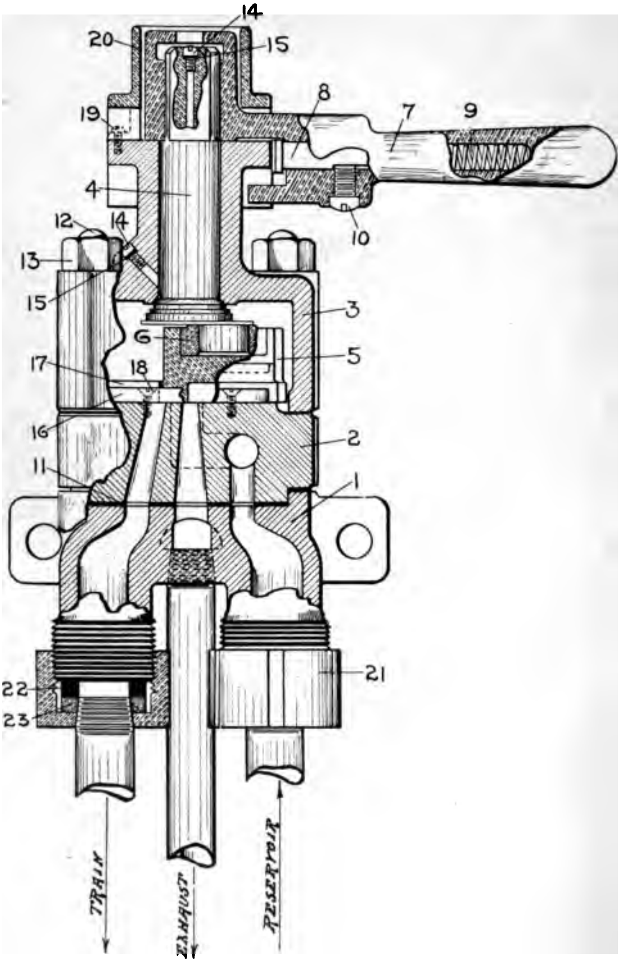

FIG. 36. Sectional Diagram of Motorman's Valve and Handle.

The National New Improved Motorman's Slide Type Valve

Referring to the sectional drawing (Figure 36) the appliance consists essentially of a sliding valve (6) with ports on its lower face so arranged that they register at the proper time with suitable ports in the valve seat (2) to make the necessary connections for the desired braking applications. The valve seat contains three ports which connect with the main reservoir, brake cylinder and atmosphere respectively. The slide valve (6) is manipulated by turning the eccentric spindle or stem (4) by means of the removable handle (7) which fits over the end of the valve stem at the opposite end of the eccentric; this handle moves through an arc of about 120° in turning from release position at the extreme left to emergency position at the extreme right. It is provided with a latch (8) which engages with the notches in the top plate.

The handle can only be inserted or removed when the valve is in "lap" position and the ports are blanked so that there is no connection whatever between any of the three ports in the valve seat. When the handle is removed the mechanism is securely safe-guarded from tampering by passengers, by a protecting shield (20) fitted over the valve bonnet (3), which prevents operation of the valve without the handle provided for that purpose. On the left side of the bonnet near the valve seat is located an oiling orifice which has a screw cover (14) and a gasket (15). The shaping and proportioning of this oil cup is such that it will contain sufficient oil for over 150,000 applications of the valve.

The design of the sliding valve is such that it wears itself into position, adjusting itself to a proper seat without attention or repairs. The valve bonnet is screwed to the face (2) by the Tee bolts (12) which are fitted with nuts (13). Figure 37 illustrates the various positions of the handle corresponding to the registration of ports in the sliding valve and its seat. With the handle at the

extreme left the positions and operations which occur in moving the handle through its successive steps are as follows:

Position One, Quick Release or Emergency Release Position

An unobstructed passage or port in the slide valve provides a connection between the train line and atmosphere through the sliding valve; in this position a very quick release of brakes will occur due to the discharge of air through the large opening.

Position Two, Running Position and Service Release

The brake cylinder is connected to the atmosphere through an opening of restricted size in the valve seat which gives a graduated release of the brakes. A spring actuated pawl (8) arranged directly in the handle comes in contact with an offset on the motorman's valve cap and defines this position. The operating handle should be placed in this position when the car is running down a grade and the motorman has admitted a trifle too much air in the brake cylinder, thereby giving a slightly too strong application of the brakes and decreasing the speed of the car more than desired. By moving the handle to service release position the brakes can be partially released by exhausting a small quantity of air which reduces the pressure while still retaining a considerable pressure in the brake cylinder when the handle is thrown back to lap position. This position is also employed in stopping the car by gradually reducing the pressure in the brake cylinder as the speed is reduced; this will give a smoother and more agreeable stop than if all the pressure is retained until the car comes to a dead stop.

Position Three, Lap Position

When the handle is moved to this position all ports in the valve seat and in the sliding valve are blanked so that there is no connection between any of the three ports in the seat: in this position only can the valve handle be removed. This position serves several purposes, the most important of which is that removal of the handle renders

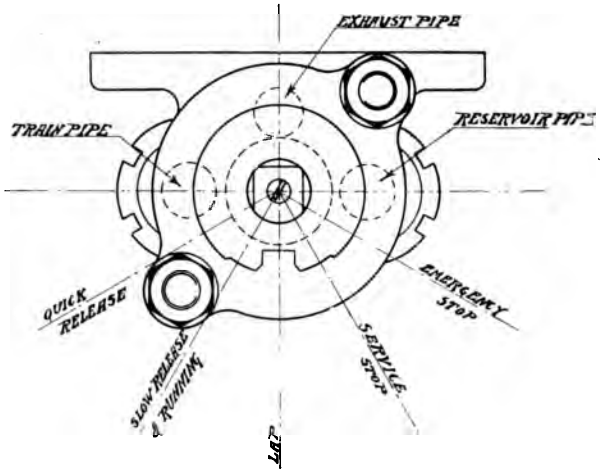

FIG. 37. Various Positions of Operating Handle

the valve neutral. It is also possible to apply the brakes with this valve, then move the handle to lap position, take it to the other end of the car and release the brake with the valve on that end.

Position Four, Slow Service Application

With the handle in position for service stop a connection through a graduated port area is made from the main reservoir and air under pressure is admitted gradu-

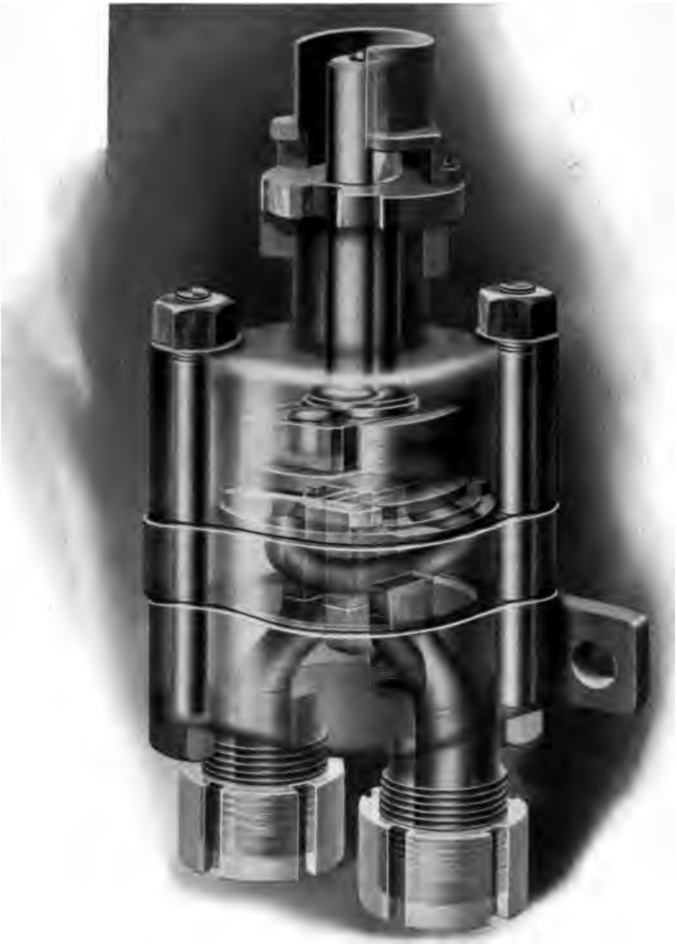

FIG 38. Phantom View of Motorman's Valve

ally into the brake cylinder, thereby making a gentle stop with just enough air to accomplish the work. This position is determined in a similar manner as the position for running and slow release application previously explained. The area of the admission openings in the National improved motorman's valve have been considerably increased over formerly made types to meet the demand for quicker application of brakes due to heavier cars and higher speed. A long and narrow triangular shaped groove has been made in the admission orifice to graduate the admission of air which in most types of valves, is admitted too suddenly.

Position Five, Emergency Application Position

In this position the large and unobstructed port connects the main reservoir to the brake cylinder, allowing maximum pressure to apply full braking force almost instantaneously. Such application should never be made except in dire necessity. When making an emergency stop the rails should also be sanded to obviate all possibility of sliding wheels with a consequent bad stop.

Installation of the Motorman's Valve

The motorman's brake valve should be attached to the vestibule framing or dash rail by means of the bracket for the stud and nut attached to the back of the valve for that purpose. Its position between the controller and hand brake should be such that the motorman can readily rest his hand on the handle when in "lap" or "release" position. The margin of space between the brake handle and controller should be sufficient to permit movement of the operating handle throughout its entire range without interference. The best height for mounting the motorman's valve is usually from 36 to 42 inches from the platform to the handle. In general the valve can be mounted on a hand rail on an open end car and at a convenient height in a vestibuled car.

The lower end of the valve is provided wtih three openings, two of which are equipped with unions for half-inch iron pipe. The one on the right on the front, marked R, connects to the main reservoir pipe and the opening on the left in front, marked T, is connected to the train pipe. The third opening in the rear, marked E, nearest to the supporting stud, is for the exhaust pipe to atmosphere.

A pipe is connected to this last opening of such length as to extend beneath the platform and if the noise of escaping air when making a release is objectionable, a muffler should be employed, or a piece of pipe extending back under the platform of the car some six or eight feet, is generally sufficient to suppress the noise. The branches for the train pipe and main reservoir pipe are provided with union spanner nuts and brass ferrules; the latter should be screwed on to the end of the pipe until the pipe is just flush with the other side of the ferrule which should be sweated on with solder. The end of the pipe should then be filed off even with the ferrule to form a smooth face for the union gasket and to ensure a good joint.

Maintenance of the Motorman's Valve

The motorman's valve should be taken apart and cleaned carefully in gasoline at intervals, depending on the severity of the service. The oil pocket in the valve contains a sufficient supply to allow about 150,000 applications of the valve which is ordinarily equivalent to six months of service. The sliding valve and its seat should be covered with a special grease of light body and minimum density, which experiments by this Company have shown to give best results. This special grease will be supplied at nominal cost. The slide valve is made with an oil reservoir in the upper side. Four small holes lead down from this reservoir to the valve face. These holes are located so that they are never uncovered by the ports with the result that the oil is fed down from the reservoir only in a sufficient quantity to keep the valve seat well covered. To

fill the reservoir a small hole is drilled through the entire length of the valve stem. Oil poured in at the top of the stem drops directly into the reservoir. The stem itself is oiled through an opening in the side of the casting enclosing it.

The difficulties of regrinding the seat, should it become necessary, are obviated by screwing the guides to the

FIG. 39. Valve Entirely Dissected

seat casting instead of having them an integral part of this casting. On removing these guides the valve seat extends out beyond any other part of the casting and this permits the seat to be surfaced in a lathe. To prevent the valve being placed on the seat in a reversed position one of the guides is made slightly higher than the other so that the valve will not seat properly unless placed in the right position.

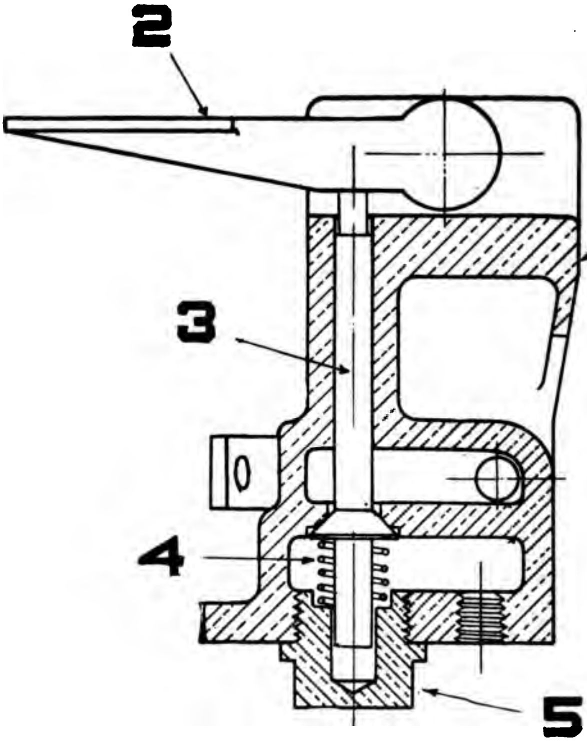

FIG. 40. Sectional Diagram Type "C" Sander Valve

The National Type "C" Sander Valve

A feature which is of the greatest importance in obtaining proper operation of the air brake, assuring the greatest possible negative acceleration of the car and at the same time preventing the wheels from skidding with the consequent formation of flats, is the proper sanding of the track. This can be accomplished in the most economical way by the National Pneumatic Track Sanding Valve which is designed to be fitted to the motorman's valve.

The arrangement of the track sanding valve directly above the motorman's brake valve, as shown in Figure 41, permits the motorman to apply sand to the track exactly when it is needed; and thus it will be evident that besides assuring a positive smooth stop, it also prevents the extravagant and wasteful use of sand which it is impossible to avoid with the majority of track sanding devices. Though this feature may at first appear of little importance, the element of cost is the least important to be considered, for many times a very serious accident may be avoided if sand is available to assist the brakes; it is well known to all railway officials that many serious accidents in the past have resulted from a lack of sand at the critical moment.

Construction of Type "C" Sander Valve

Reference to the sectional drawing (Figure 40) will show that the sander valve consists of a body (1) made of a brass casting. The use of brass makes the valve of light weight and at the same time insures ample strength and great durability. The valve body contains a cylindrical brass stem (3) which is supported on a stout retractile spring (4). At its upper end the spring presses against an umbrella-shaped disk fitted in a groove machined in the body of the valve. The pressure of the spring combined with that of the reservoir line pressure

FIG. 41. Motorman's Valve and Handle, with Type "C" Sander Valve Attached

keeps the disk tightly seated so that no air can escape to the rectangular-shaped passage above. The plug (5) which is screwed in the lower end of the body permits easy access to the few working parts of the valve.

Operation of Type "C" Sander Valve

The sander valve is operated by means of the handle (2) which when pressed causes the disk to be forced down allowing air to flow into the cored passage above which is connected with the sand box, and thus blow the sand from the containing receptacle onto the rails.

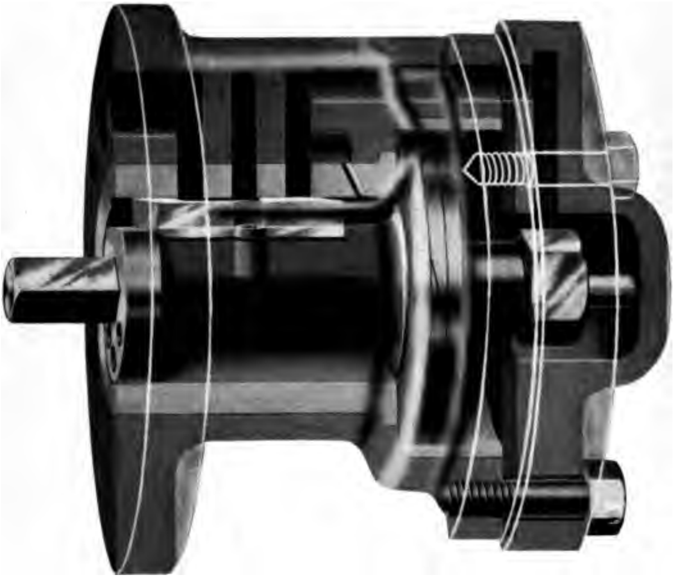

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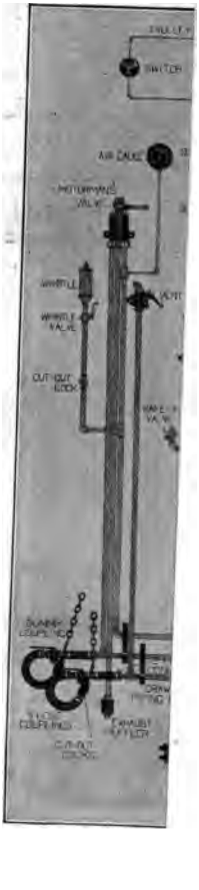
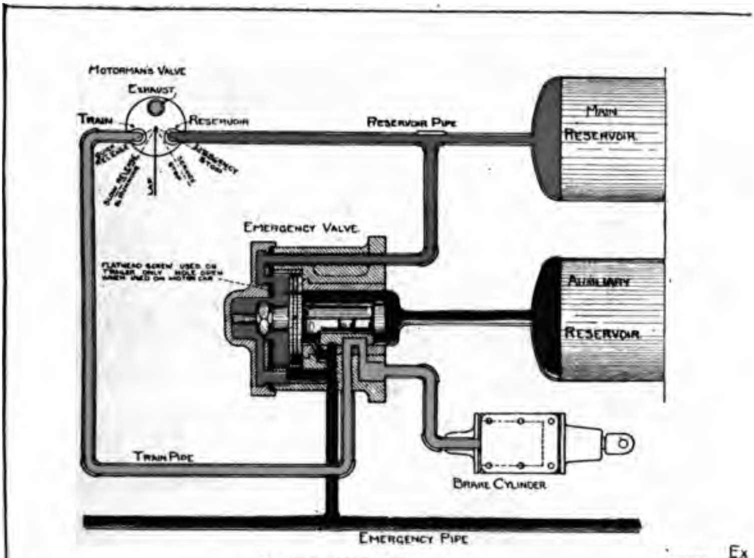
FIG. 43. Showing Ports, Air Passages and Details of Construction

the connecting port in the valve and enters the brake cylinder through the port to the left. Should the train separate or the conductor pull the emergency valve, air escapes from the emergency line and the pressure behind the piston is reduced. This causes the piston and valve to be pressed to the right by the auxiliary reservoir pressure in the slide valve chamber. When this occurs: (1) the port to the brake cylinder is uncovered and opened to the slide valve chamber, and as this chamber is connected to the auxiliary reservoir the brakes are set by the equalization of pressures in the auxiliary reservoir and the brake cylinder. (2) The train pipe line is connected direct to the emergency pipe line from the slide valve and the


SWITCH
AIR GAUGE
MOTORMAN'S VALVE
WHISTLE
WHISTLE VALVE
CUT OUT COCK
DUMMY COUPLING
HOSE COUPLING
EXHAUST MUFFLER
CUT OUT COCKS



Running Position

emergency pipe line is given an additional opening to atmosphere. (3) This small port to the left of the valve seat is covered by the valve and air is prevented from passing to the emergency line from the auxiliary reservoir. (4) The connection between the main reservoir and emergency line is cut off by the seating of the small screw hole in the piston so that no air can pass into the emergency line from the main reservoir.

To release the brakes after they have been set by the reduction of pressure in the emergency pipe line, the openings of the emergency line to atmosphere are first

FIG. 46. Showing Valve Complete and Valve Dissected

closed and the motorman's valve moved to emergency position; air then passes from the main reservoir through the motorman's valve and train pipe lines into the emergency pipe line which is connected to the train pipe line through the port in the slide valve. The increase of pressure in the piston chamber which is connected to the emergency pipe line and the pressure of the spring previously mentioned, causes the piston and valve to move to the normal position. When this occurs the motorman's valve may be thrown to release position; and the brake cylinder will be vented to atmosphere through the train pipe line, at the same time the connections are re-established between the

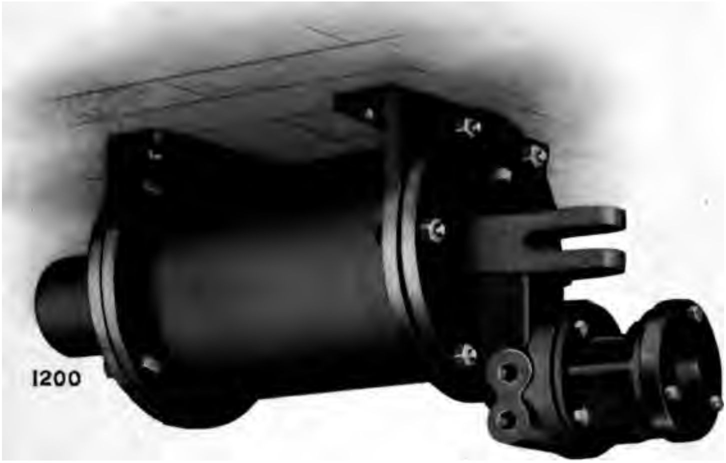


FIG. 47. Valve Mounted on Brake Cylinder

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FIG. 48. Valve Mounted on Bracket

emergency pipe line, auxiliary and main reservoirs and the pressures in these are equalized.

Installation and Maintenance of Emergency Valve

The emergency valve is well oiled before it leaves our shops with a special paste grease and this lubrication should be sufficient for at least six months or a year, depending upon the frequency of service. A coarse grade of engine oil is recommended for lubrication. The parts of the valve are carefully adjusted before it is shipped and no adjustment is required when it is to be installed. The valve should be mounted on the emergency valve bracket which is located at any convenient point under the car body. If a bracket is not used, a special head is provided on the brake cylinder on which the emergency valve is supported by four cap screws (15). The piston packing ring should not be removed from the piston at any time. The flat head screw in the piston head is to be used only when the valve is applied to trailers. The hole should be left open when the valve is used on motor cars. In case the valve is separated from the brake cylinder head or bracket, care should be taken to keep the open ports protected from dust and dirt. When installed the valve should be operated several times per week as a precaution that it is in proper working order at all times whether required or not. When used on high-speed interurban cars it should be worked at the commencement of each trip.

Chime-Whistle Outfit

On high speed cars it has been found from experience that an air whistle is a very essential part of an air brake equipment on account of the greater distance at which it can be heard than an ordinary gong. Such a means of warning is very convenient on air brake equipped cars

because the air for its operation is used from the same reservoir as that for the brakes. The air whistle can also be arranged to occupy much less space than a gong and can be operated either by foot or by hand, as shown in Figures 49 and 50 respectively.

It is frequently desirable to provide an arrangement by which the air whistle will not draw too heavily from the main reservoir and thereby affect the proper opera-

FIG. 49. Whistle Outfit with Foot Attachment

tion of the brakes. This consists in the use of an auxiliary main reservoir which is connected to the compressor and to the whistle, as well as to the governor. It is also connected to the other main reservoir by a pipe in which is placed a check valve to prevent the escape of air from the main reservoir proper, through the whistles; all the air for blowing the latter is utilized from the auxiliary reservoir provided for that purpose which is charged by the compressor. The whistle outfit comprises a Chime-Whistle, a Whistle-Valve and a special Cut-out Cock.

The Whistle-Valve is of the globe type with valve supported on its seat by a spring with the assistance of air pressure, the stem of the valve passing through the body and engaging with the lever to which the whistle cord is fastened. A pull of the cord causes the lever to push in the stem and compress the spring and unseat the valve which causes air to flow through a restricted orifice in the whistle and emit a powerful but agreeable sound of great carrying power. Release of the cord causes the spring under the valve aided by the air pressure, to force the valve on its seat and cut off the air supply.

The Cut-out Cock is introduced in the whistle pipe to enable the air supply to be cut off whenever required.

When a car is equipped with controlling apparatus at each end, a similar whistle outfit should be used at both ends.

Installation of the Whistle Outfit

Wherever feasible the whistle set should be located just above the roof of the motorman's cab and connected to the whistle valve by a ½-inch pipe; and connected to reservoir at the nearest point also by a ½-inch pipe and a ½-inch cut-out cock introduced at a convenient place, inside of the cab if possible. A cord may be run from the end of the whistle valve lever across the cab with sufficient slack so as to be easily gripped

FIG. 50. Standard Whistle Outfit

by the motorman. The whistle valve should be placed inside the cab and as near to the whistle as convenient; and the valve should be so located that the pressure of the air tends to close it.

On open cars the whistle may be installed below the platform and either operated by means of a piece of wire attached to the end of the whistle valve lever and brought up through the floor, or else by means of a foot device as on ordinary gongs.

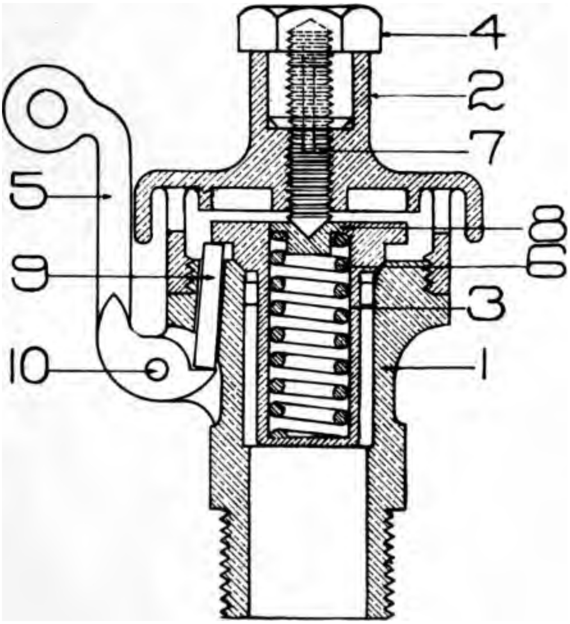


FIG. 51 National Safety Valve

National Safety Valve

A very essential part of an air brake equipment is a safety valve which is employed as an auxiliary to the governor to prevent overcharging of the reservoir. These safety valves are also used with the portable and stationary compressor outfits and have been designed with the greatest care after much experimental work.

Construction of Safety Valve

The small number of parts and the simplicity of construction of the National Safety Valve is fully shown in the sectional drawing (Fig. 51). The body or containing casting is of brass made in halves and screwed together. The lower half of the body contains the valve seat (1) and the valve (3) which is of the so-called "wing" type. The valve bonnet (2) contains the adjusting screw (7) by means of which the tension of the spring (6) is adjusted so as to keep the valve (3) seated against any desired reservoir pressure. The adjustment of this screw is varied by means of a slotted key which is furnished with each valve and which is entirely separate from the valve. After varying the adjustment the lock nut (4) should be securely locked in place. By manipulating the adjusting screw (7) the pressure of the spring can be set so that it will hold the valve in its normal position until the pressure in the reservoir exceeds this value whereupon the valve will lift and vent air to atmosphere through the opening in the side of the case. This will continue until the pressure is lowered to that for which the spring has been adjusted when the valve will again be seated.

To enable the safety valve to also serve the function of a reservoir exhausting valve when a car is to be put out of commission it is provided with a handle (5) which when pulled down causes its projecting end to force the spring lifting pin (9) upwards thereby lifting the valve (3) from its seat and exhausting air from the tank.

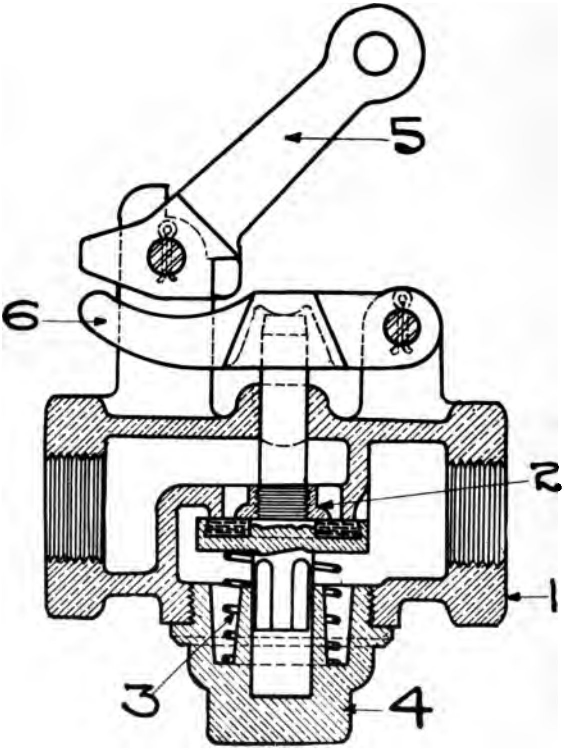


FIG. 52. Sectional View of Conductor's Valve

Installation of Safety Valve

The safety valve is inserted in the reservoir pipe line leading to the motorman's valve at a point as close to the reservoir as practicable, or it may be installed at the end of the car. It should be tightly screwed into a Tee and placed in a vertical position. The adjustment of the valve should be such that it will open when the pressure is ten pounds above that at which the governor should normally stop the action of the compressor.

Conductor's Valves

The conductor's valve or car discharge valve is used as a safety device accessory to emergency valves.

Construction of Conductor's Valves

Referring to the sectional drawing Fig. 52, the parts of the Conductor's Valve consist of a casting or body (1) made of malleable iron enclosing the steel valve stem (2). A retractile steel spring (3) is fitted in a recess in the lower part of the cap nut (4) which is screwed in the valve body; the spring presses against the stem and holds the valve normally closed.

A pull of the cord presses the lever (5) against the end of the stem (6) overcoming the resistance of spring (3) and allowing a small amount of air to be vented from the pipe, thereby reducing the pressure in the emergency pipe line and causing the latter to perform its function as previously described.

Installation of Conductor's Valves

Conductor's valves are usually installed in the vestibule of a car above the door. A branch pipe is run from the emergency pipe line to the conductor's valve; a ½-inch cock is inserted in this pipe to enable the valve on the car to be cut out of service when desired. The threaded opening on the sides connects with the emergency pipe line.

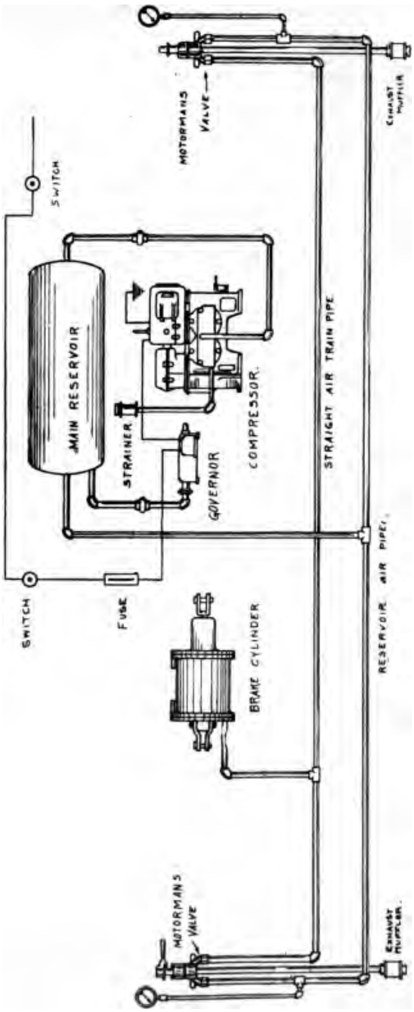


FIG. 53. Straight Air Brake Equipment for Motor Car

Instructions for Operating National Straight Air Brakes

The compressor is started by closing the snap switch which allows current from the trolley circuit to flow through the switch and fuse, thence through the governor which is automatically closed by the current, then through the motor and thence to ground. The air compressor at once begins to operate and charges the main reservoir. The compressed air flows to the valve seat of the motorman's valve. The motorman's valve is provided with notches which indicate the position of the handle for the various operations of the valve. While it is a comparatively simple matter for a novice by paying attention to the notches to operate the brakes after a fashion, quick, accurate and agreeable stops are only made after some practice. The personal equation enters so largely into the problem of operating brakes properly and efficiently that it is impossible for any considerable number of motormen to obtain equal results at the start. The practice which a careless or indifferent motorman may get into of "fanning" the brake handle is a pernicious habit and wastes air excessively, besides causing unnecessary wear and tear on the trucks and all other parts of the equipment.

The operating valve handle must always be inserted at "lap" position which is readily apparent from the enlargement of the slot in the top plate for that purpose and withdrawn at the same position when changing from one end of the car to the other; moving the operating handle to "lap" position causes the ports of the valve to be so connected that air can neither be admitted to or discharged from the brake cylinder. By turning the handle to the extreme left the valve is placed in "full release;" moving the handle to the right as far as the small notch opens the small port and a further movement to the right opens the large port.

A large quantity of compressed air will issue from a very small opening in a short interval of time, hence to apply the brakes lightly throw the handle to the small notch and immediately move it back to "lap" position. The air previously admitted to the brake cylinder is retained, thus keeping the brakes applied. Partial release of the brakes is effected by moving the handle to "release position" and quickly returning it to "lap" which permits a portion of the air to be exhausted, reducing the pressure in the cylinder.

To secure the quickest possible stop the maximum pressure which will not cause skidding of the wheels should be applied throughout the stop and the greater the speed the greater the pressure that may be applied without causing skidding. The co-efficient of friction of brake shoes upon wheels varies from .27 at five miles per hour to about .10 at 60 miles per hour, hence to produce the same retarding effect at 60 miles per hour, about three times the pressure should be applied to the shoes at the higher speed as could be safely applied at the lower speed.

It follows generally that to stop a car quickly, full operating pressure should be applied instantly and gradually released as the car decelerates. A smooth and easy stop will also be produced by this method as the sudden checking of speed which jostles passengers is prevented. To effect a "service stop" therefore, admit from 20 to 30 pounds of air pressure at once when commencing to stop, by partially opening the large port and release it slowly step by step as the speed falls, retaining about ten or twelve pounds in the cylinder until the car comes to a full stop. After a short experience a motorman will learn to gauge the distance necessary in which to effect a stop from a given speed and thus make a smooth and agreeable stop with but one application of the brakes. An intermittent series of applications and releases while making a stop produces an annoying motion of the car, wastes air excessively and is in every sense bad practice.

In making an "emergency stop" apply full pressure, usually 60 pounds, at once, regardless of whether the controller is turned off, then apply sand and slightly release the pressure as the car decelerates.

When the signal to start the car forward is received, the handle should be moved to "release" position before power is applied to the car motors. A very common error with beginners is to apply the brakes too strong on commencing to descend a grade. On account of the momentum of the car and a certain mechanical inertia inherent in braking systems, the car will not instantly take the desired speed; apply the brakes lightly at first, keep the handle on "lap" notch and wait a little for the speed to be checked. If then the car fails to slow up, admit a trifle more air and if the grade is long, continue the operation (if necessary) until off the grade.

In putting a car in the barn or leaving same, the hand brake should always be set up to prevent persons from meddling with cut-out cocks. In taking a car from the barn first see that all the cocks are accurately set and that there is sufficient air in the reservoir. Place the handle of the operating valve in position and move it around to "emergency," then back to "release" to be sure that it works freely. To feel sure that wrong connections have not been made, test the brakes for operation both in "service" and "emergency" positions; if these tests are satisfactory and the proper pressure is supplied to the brakes, they may be depended upon to work properly.

Making up Trailers

In making up trains much care must be exercised in connecting hose couplings so that there will be no escape of air. Open all cut-out cocks excepting those on the rear of the last car and on the front of the motor car; these must be closed.

Before uncoupling the cars, close the cocks and disconnect the hose before taking out the draw bar pin.

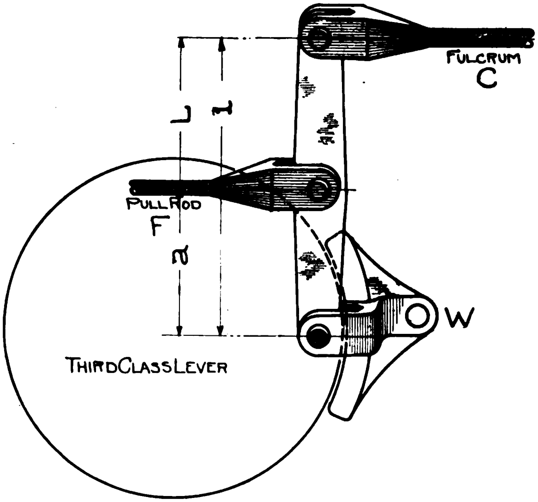
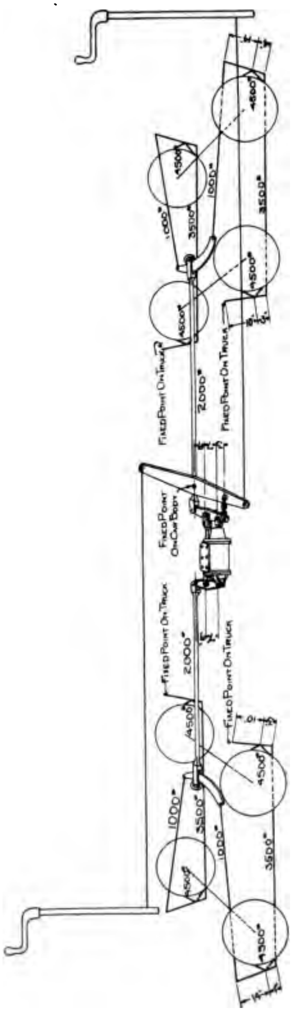


FIG. 56. Third Class Lever

Brake Leverage

The determination of the proper proportions of brake levers or of the forces acting upon different pins involves two forces and two distances; one of these forces may be treated as an applied force to one of the pins, while the other is that applied to another of the pins and the last is the "fulcrum" for the other two. The two distances concerned, are those between the fulcrum pin and the two pins at which the forces are delivered and applied respectively.

For every problem the product of the force applied at one pin and its distance from the fulcrum pin equals the product of the force delivered at the other pin and its distance from the fulcrum pin.



TOTAL BRAKE CYLINDER PRESSURE 2600 AT 70 LBS.

FIG. 57. Foundation Brake Gear

There are three classes of levers: (1) In a lever of the first class the fulcrum is between the point at which the weight or resistance is applied and the pull rod (Figure 54). (2) In a lever of the second class, the weight or resistance is applied between the point of action of the fulcrum and the pull rod or the point at which the force is delivered, (Figure 55). (3) In a lever of the third class the points at which the force is applied is between that of the weight or resistance and the fulcrum, (Fig. 56).

In every problem of levers the relation between the force exerted or the pull P in pounds and the weight lifted, resistance overcome or pressure exerted, W, in pounds is determined by the equation $P \times L = W \times 1$; where L is the lever arm of P in inches and 1 is the lever arm of W in inches.

Solving this equation for the three classes of levers we obtain:

For Levers of First Class

$$P = \frac{W \times L}{1} \quad W = \frac{P \times L}{1} \quad 1 = \frac{P \times a}{W - P} \quad L = \frac{W \times a}{W - F}$$

For Levers of Second Class

$$P = \frac{W \times L}{1} \quad W = \frac{P \times L}{1} \quad 1 = \frac{P \times a}{W - P} \quad 1 = \frac{W \times a}{W - P}$$

For Levers of Third Class

$$P = \frac{W \times L}{1} \quad W = \frac{P \times L}{1} \quad 1 = \frac{P \times a}{W - P} \quad 1 = \frac{W \times a}{W - P}$$

The diagram, (Figure 57) shows a general style of foundation brake lever system applicable to any double-truck motor car, the total (normal loaded) weight of which is assumed to be 40,000 pounds; hence the braking force should be $40,000 \times .90 = 36,000$ pounds, which corresponds to the combined brake-shoe pressure exerted by the brake cylinder pressure through the foundation brake lever system. This pressure applied to eight wheels

would give 36,000 ÷ 8 = 4,500 pounds against each brake shoe.

Starting at dead lever, which in this case is a lever of the second class and assuming that the short end is six inches and the long end 15 inches, then by the formula we have: $P = \frac{W \times l}{L}$

$$P = \frac{4500 \times 10}{13} = 3500 \text{ pounds.}$$

Reference to the diagram will show that this force is the strain on the bottom of the rod. This goes over the live lever to top rod and we have according to formula:

$$W = \frac{P \times L}{l} = \frac{3500 \times 4}{14} = 1000 \text{ pounds.}$$

The sum of the two forces of the two top rods must be exerted by the cylinder levers. By the formula

$$P = \frac{W \times L}{l} \text{ we have } \frac{2000 \times 9}{7} = 2600$$

pounds. A force of 2600 pounds must therefore be exerted by the brake cylinder. If the diameter of the brake cylinder is 8 inches, the area will be $r^2 = 3.1416 \times 16 =$ 50.2 inches. The pressure per square inch necessary to give a total of 2600 pounds is $\frac{2600}{50.2} = 51.7$ pounds approximately.

If the car is equipped with not more than two motors mounted on one truck, it is obvious that the weight on one truck is less than on the other by the weight of the two motors, and allowance for this should be made in the cylinder levers. This is done by simply increasing or decreasing the power in changing the position of the tie rod C. which connects the two cylinder levers. Holes are provided in the cylinder levers for that purpose.

Foundation Brake Rigging

The foundation brake rigging on a car is divided into the levers, rods, shoes, etc., on the trucks and the levers,

rods, etc., on the car body; hence when cars are equipped with air brakes it will usually be found that these parts on the truck being an integral part of the design of the trucks, cannot be changed; the change must therefore be made on the car body levers.

Wherever feasible, the brake beams should be so hung that their distance above the rail will be uniform regardless of the weight of the car. Such practice will largely reduce the danger of flat wheels because the loading and unloading of the car will not affect the piston travel which may be adjusted for the proper length of stroke irrespective of whether the car is loaded or not.

The hand and air brakes should be so designed that they will operate in synchronism; in other words, so that all the levers will move in the same direction when the brakes are applied by hand or by air. If they operate against one another, that is, if hand power works against air power only one can be applied at a time which will cause annoyances in cases where the air brake is applied upon cars which are to remain upon a grade for a while because the hand brakes cannot be applied until the air brakes are released Various other minor objections also obtain, and from both the standpoint of safety and good practice it will be found that the simultaneous operation of both air and hand brakes will be the most successful arrangement.

It is more practicable to fasten brake cylinders to car bodies by means of an iron plate instead of a wooden block since the latter will shrink and cause the bolts to loosen and permit movement of the brake cylinder every time the brakes are operated, and since this movement will be taken up by the piping system, leaky joints may develop.

It is quite essential that the brake rods should be as nearly parallel as possible with the longitudinal line through the center of the car when the brakes are applied. The brake levers should also stand as nearly at right angles to the rods as possible when the brakes are applied.

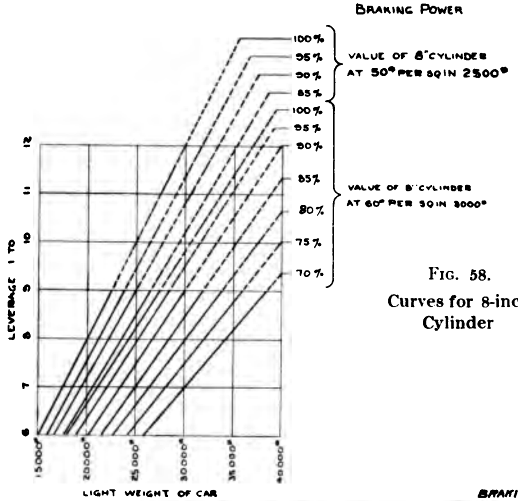


FIG. 58.
Curves for 8-inch Cylinder

A Total Leverage of 9 to 1 Should not be Exceeded

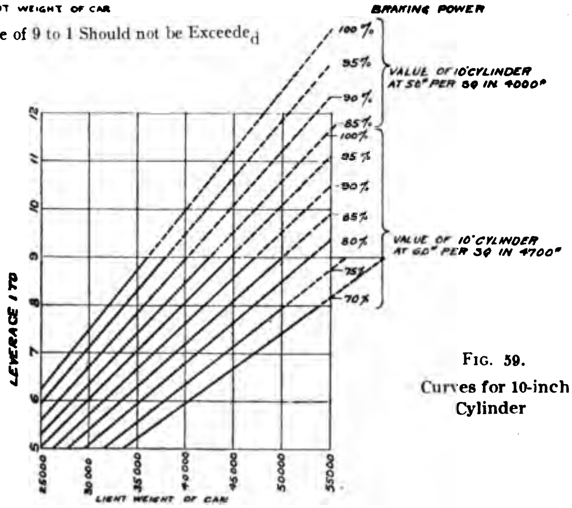


FIG. 59.
Curves for 10-inch Cylinder

The following table which is taken from an article by Mr. E. H. Dewson, on Electric Railway Braking, (Electric Club Journal, February, 1905,) gives an approximate relation of the ratio which the pressure applied to the brake shoes should bear to the total weight upon the braked wheels to produce a brake friction just equivalent to the adhesion of the wheels to the rails:

Speed		Approximate Ratio of Total Pressure on Brake Shoes to Total Weight on Braked Wheels			
Ft. Per Sec.	M.P.H.	Co.-Eff. of Adhesion			
		0.30	0.25	0.20	0.15
11	7.5	1.20	1.04	0.83	0.60
22	15	1.41	1.18	0.94	0.70
29	20	1.64	1.37	1.09	0.82
44	30	1.83	1.53	1.22	0.92
59	40	2.07	1.73	1.38	1.04
73	50	2.48	2.07	1.65	1.24
88	60	4.14	3.47	2.77	2.08

As is obvious from the above table, an average co-efficient of adhesion, .25, permits a brake power of 90% of the weight of the car to be applied without danger of skidding the wheels at low speed when the co-efficient of friction of brake shoes is a maximum. A safe practice is to apply a 90% brake power to idle axles and 100% to motor equipped axles on account of the rotative energy of their armatures which is equivalent of from 3% to 6% of the inertia of the car.

The determination of the size of brake cylinder required by a given unloaded car involves the area of piston, pressure per square inch and stroke. The standard practice of steam railways is 60 pounds per square inch for maximum emergency pressure with 8-inch piston travel, which is also a good standard for electric railways. Piston travel equals the average amount of the wheel shoe

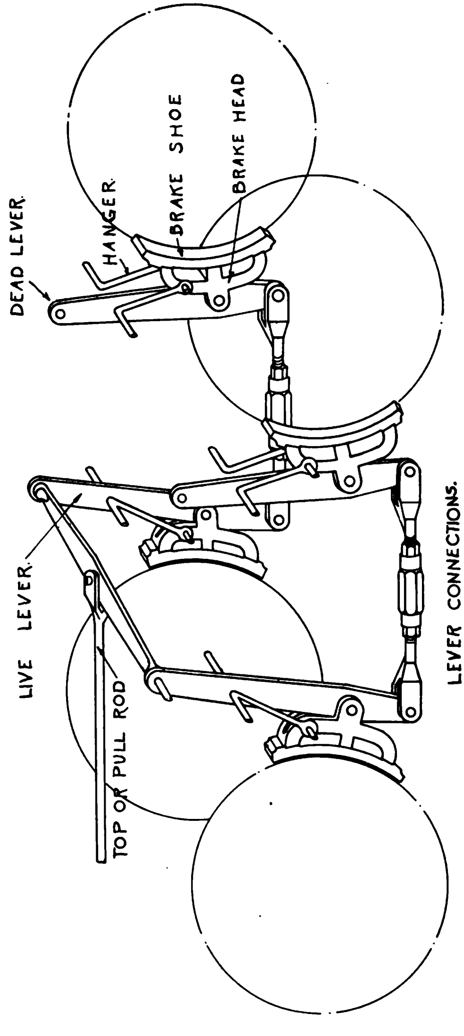


Fig. 60. Illustrating Inside Hung Brake Shoes

slack or clearance multiplied by the total gain by leverage, disregarding travel due to springing of levers.

The table below is based on the above considerations:

Division of Cylinder in Inches	Force of Piston at 60 Pounds	Total Leverage Ratio	Weight of Car with Brake Power Equal to		
			90%	100%	110%
8	3,000	12 to 1	40,000	36,000	32,750
10	4,700	11 to 1	57,800	51,700	47,300
12	6,700	$10\frac{3}{4}$ to 1	80,000	72,000	65,500
14	9,200	10 to 1	102,300	92,000	83,600

In all cases where practicable the brake shoes should be hung inside the wheels and the hangers so inclined that gravity will cause the shoes to swing clear of the wheels. Outside hung brakes tend to cause the forward end of the truck frame to tilt down when brakes are applied with a resulting slack off of the shoes at this end. The other end of the truck tilts up which tightens the shoes and may cause the wheels to skid since the friction at the different connections prevents an equalization of pressures under the new conditions. With inside hung brake shoes, brake beams are unnecessary, and each shoe is independent of the others. The appearance of the truck is also greatly improved with inside hung shoes and the car rides easier.

Figure 61 shows diagramatically the design of National Standard Sets of Body Levers which are sent out on all *orders* including levers unless otherwise specified, or unless the type of car is so radical as to demand an alteration of design. In this brake lever system which was adopted after long experience, both push rod and cylinder levers have three points at which the rod may be connected; the outside holes show maximum and minimum leverages and hence maximum and minimum braking powers that are obtainable from the cylinders for which they are intended.

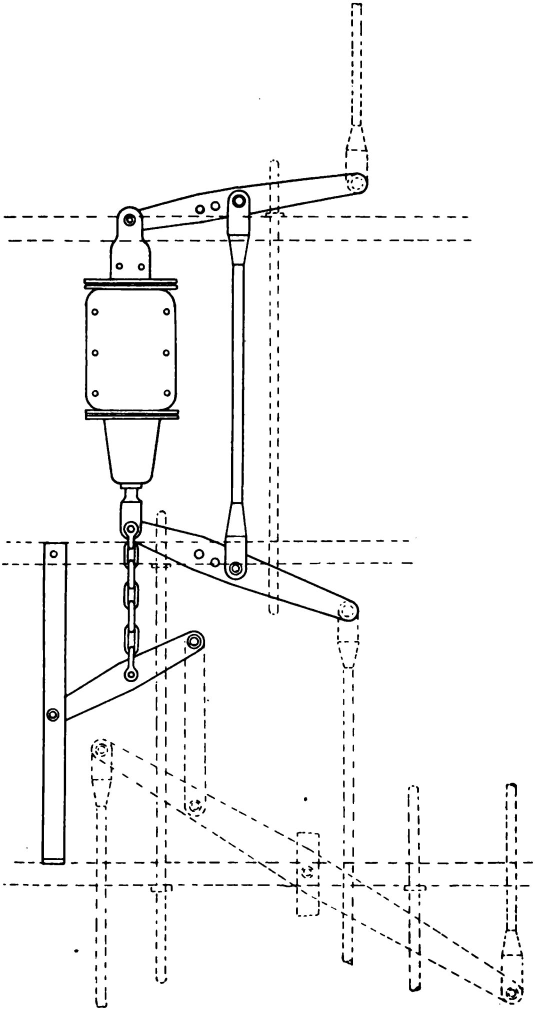


FIG. 61. Brake Cylinder and Standard Body Levers

Piston Travel

In air brake practice there are several terms used in connection with the travel of the piston: (1) The Standing Travel is the distance the piston is forced outward in setting the brakes upon a car at rest. (2) Running Travel is the length or distance the piston is forced out when the brakes are set upon a moving car. The running travel always exceeds the standing travel on account of the flexibility in brasses, the downward pull of the shoes upon the wheels, the play between boxes and pedestals and to all the various factors which act to increase the lost motion in the brake rigging under the action of car motion. Running travel is generally about $1\frac{1}{2}$ inches greater than standing travel. (3) False Travel is an abnormal length of piston travel caused temporarily by faults in track construction or other unusual stresses which may occur when the car is in motion.

The effect of a short piston travel is to cause a greater brake cylinder pressure with a given reduction in train pipe pressure; for instance: a 15-pound reduction in train pipe pressure gives a brake cylinder pressure about 40% higher with a 5-inch than with a 10-inch piston travel.

To adjust piston travel so that there will be a very uniform setting of the brakes on each car, it is necessary to employ an automatic slack adjuster. When this device is not employed, the best practice is to make the standing piston travel six inches.

Uniformity of piston travel upon the several cars in a train is of highest importance. Excessive length of piston travel causes a reduction in the brake cylinder pressure with a proportionate lowering of efficiency. Moreover, a greater consumption of air is brought about, which necessitates more frequent action of the compressor and hence, increased wear and strains. Exceedingly short length of piston travel will result in a dragging action of the brake shoes upon the wheels when the brakes are released; also there is danger of excessive brake cyl-

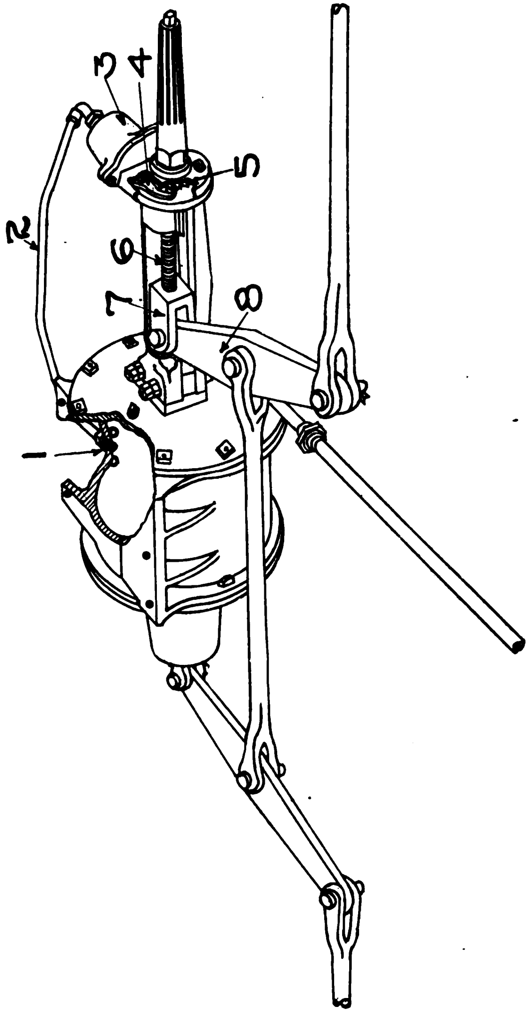


FIG. 62. Brake Cylinder and Slack Adjuster Details

inder pressure which causes skidding of the wheels when the brakes are set.

A correct piston travel is obtained when there is just enough brake shoe clearance on release of the brakes. This length of travel is ordinarily six inches as previously stated.

Automatic Slack Adjuster

The difficulties of maintaining uniformity of piston travel due to uneven wear on the brake shoes, lost motion in journals, brasses and center plates, the springing of brake rigging and the variations in total leverages has necessitated the employment of a device which automatically regulates the piston travel when cars are run-

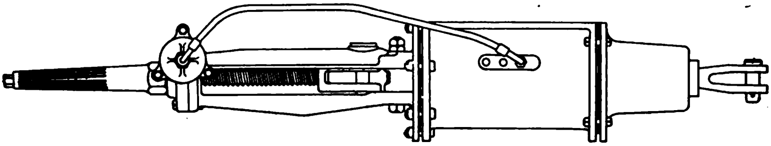


FIG. 63. Side View of Adjuster on Cylinder

ning with brakes applied. The closest and most accurate hand adjustment of piston travel will not suffice because the combined action of the factors above mentioned will change the piston travel with the first and each succeeding application of brakes. Thus frequent and troublesome adjustments of the piston travel are required while the brake efficiency is being constantly lowered. The only efficient and economical method of insuring perfectly constant and uniform piston travel, compensation for the varying effects of leverage and wearing out of brake shoes, and constancy of cylinder pressure is the use of an American automatic slack adjuster.

Referring to the illustration, Figure 62, three ports (1) are drilled and tapped in the air brake cylinder at points which are the limits of the piston travel. Fig. 63

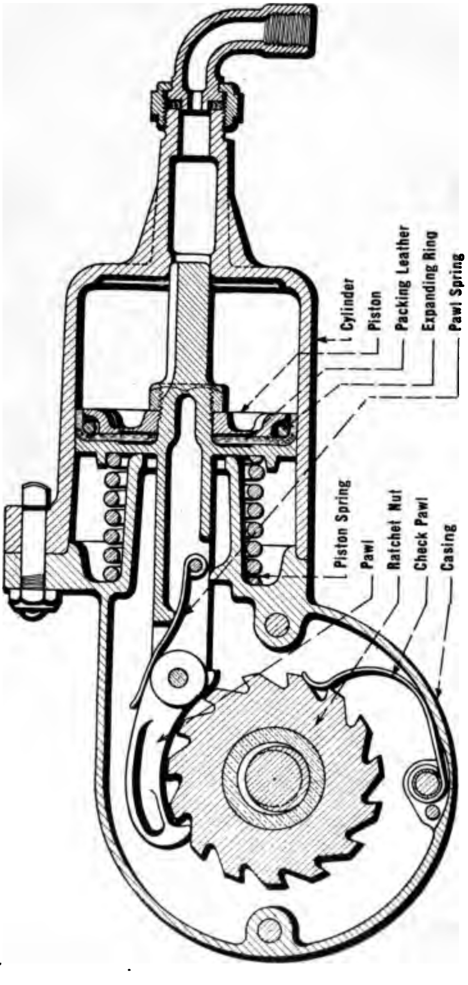


FIG. 64. Sectional Slack Adjuster Cylinder

shows the Adjuster feed pipe (2) led into the brake cylinder for 7-inch travel. From one of these ports a small pipe (2) is run to the adjuster cylinder (3). When the predetermined piston travel is slightly exceeded the brake piston discharges the function of a valve, and the compressed air issues through the port in the brake cylinder (1) flowing thence through the small pipe (2) to the adjuster cylinder, (see Fig. 64), thus operating its piston which in turn actuates a pawl (4) engaging the ratchet wheel (5) and nut on the screw. Release of brakes causes a spring in the adjuster cylinder to return the piston in the latter to its normal position, resulting in the rotation of the ratchet nut on the adjusting screw (6). The inner end of the screw carries a jaw which acts as a fulcrum for the adjustable or floating lever (8) of the brake cylinder. The adjuster mechanism is amply protected against the entrance of foreign matter into its parts.

When the piston travel does not exceed the required limit the mechanism of the automatic slack adjuster is always at rest; the slack is entirely taken up which reduces wear to a minimum.

In Figure 65 is shown a brake leverage chart, the method of using the leverage chart is shown by the following examples:

Examples on Brake Leverage Chart

Ex. 1. A passenger car weighing 80,000 pounds is to be braked 90% of its light weight, 12-inch cylinders being used, leverage being based on 60 pounds in brake cylinder. What ratio of leverage is required?

First find the braking power in pounds by following the vertical line from 80,000 on the axis marked weight of car until it meets the 90% braking power diagonal of A, and follow across from this point, as shown by dotted line, to the axis marked Braking Power in Pounds, of B, which represents 72,000 pounds braking power. Now start again with 60 pounds on the axis marked Unit

Cylinder Pressures, and follow the horizontal line from that point until it intersects the cylinder diameter diagonal marked 12-inch of C. From C follow a vertical line as shown by dotted line to the axis marked Total Cylinder Pressure, this giving the point D, which represents about 6,800 pounds total pressure on the piston. A continuation of the horizontal line through the point B, found above, meets a continuation of the vertical line through the point D of F. E lies between the 10 to 1 and 11 to 1 leverage ratio diagonals, and represents a leverage of about 10½ to 1.

Ex. 2. On a 90,000 pound car 14-inch cylinders are used, and leverage ratio is 8 to 1, based on 60 pounds cylinder pressure. At what per cent of its weight is this car braked?

Starting with the 60-pound horizontal line, its intersection with the 14-inch cylinder line is H. A vertical from H intersects the 8 to 1 leverage ratio line of F, as shown by the dotted line. Then follow a horizontal line from F, as shown, until it intersects a vertical line from the point representing the weight of the car (90,000) giving the point G lying between the 80% and 85% braking power diagonals; G then represents 82% braking power.

Ex. 3. What size brake cylinders must be used on a 100,000-pound car, if it is to be braked at 90% of its weight, leverage ratio being 8 to 1, based on 60 pounds cylinder pressure?

Follow the 100,000-pound vertical line until it meets the 90% braking power diagonal at K; then follow the horizontal line from K to the 8 to 1 leverage diagonal at L, and from L follow a vertical line until it meets the 60-pound horizontal line at M. M lies between the 14-inch and 16-inch cylinder diameter diagonals. The 16-inch cylinder would be chosen, although a corresponding higher braking power would be obtained.

Ex. 4. A 38,000-pound car, braked at 70% of its light weight has total leverage 9 to 1, 8-inch cylinders

being used. What cylinder pressure is this leverage based on?

Follow the 38,000-pound vertical line until it intersects the 70% diagonal at N. From N follow the horizontal line as shown, to its intersection with the 9 to 1 leverage line at O. From O follow a vertical line to the 8-inch cylinder line of P. P lies on the 60-pound horizontal line, showing that the leverage in this case was based on 60 pounds.

Ex. 5. If basing the leverage on 60 pounds gives us 90% braking power for a certain car, what per cent braking power will 95 pounds give us?

First assume any size of cylinder and leverage ratio desired. For example, choose those given in Example 4. Starting now with 60 pounds, we first obtain the point P and then the point O, the horizontal line from O intersects the 90% diagonal at Q. This corresponds to a weight of car of 30,000 pounds. Now start over again with the 95-pound horizontal line. Using the same size cylinder, the same leverage ratio and the same weight of car as before, the points R, S and T are successively found. T lies between the 140% and 150% braking power diagonals and would represent a braking power of about 146%.

NOTE:—See Ex. 6 below.

Examples on Shoe Clearance Chart

Ex. 1. What brake beam movement (shoe clearance) is obtained with a piston travel and total leverage of 8 to 1?

The horizontal marked 8-inch Piston Travel intersects the 8 to 1 leverage diagonal at X. Following the vertical line from X we find the brake beam movement to be 1 inch.

Ex. 2. Suppose a shoe has an allowable wear of 1½ inches with an 8 to 1 leverage as above, what additional piston travel does this require in order to completely

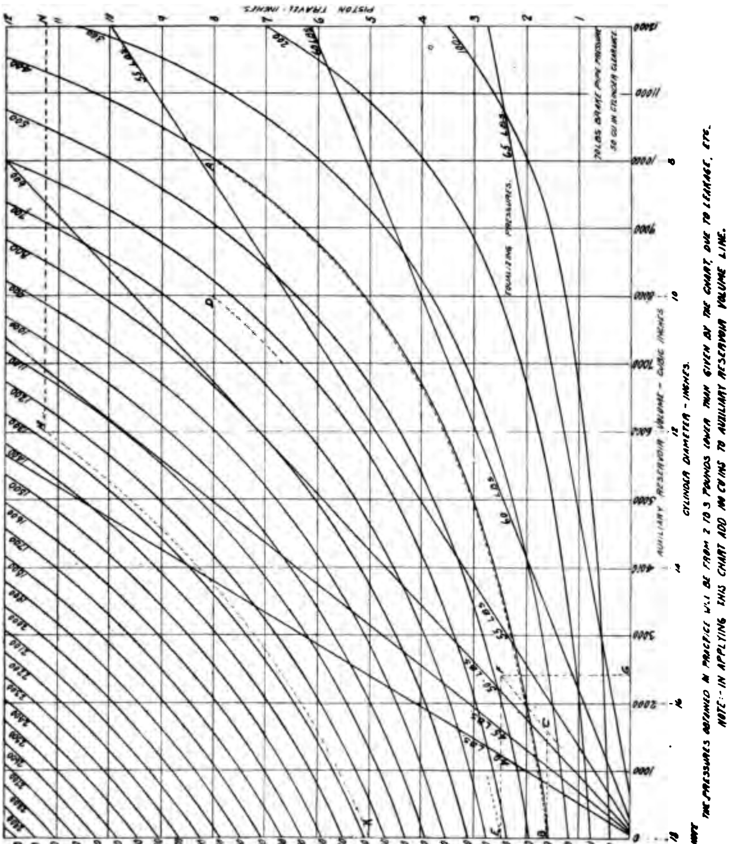


FIG. 66. Brake Equalization Chart

wear out the shoe without any adjustment of brake rigging?

The $1\frac{1}{2}$-inch vertical line meets the 8 to 1 leverage line at Y. Following the horizontal line from Y, we find the additional piston travel to be 12 inches. This is the amount of slack adjuster travel required or the amount which the piston travel must be taken up by hand in order to wear out the shoe.

Ex. 6. Given a 40,000-pound car, capacity 100,000 pounds and braking power 60% of its light weight. What will be the per cent braking power when loaded with 100,000 pounds?

Follow 40,000-pound vertical line to 60% diagonal giving the point W. When loaded, total weight on wheels is 140,000 pounds. From W follow a horizontal line, therefore, until it intersects the 140,000-pound vertical line at Z, giving 17% braking power.

Figure 66 shows a brake equalization chart. The method of using this chart is shown by the examples herewith appended:

Examples on Equalization Chart

Note: Add 100 cu. in. to line indicating Auxiliary Reservoir Volume in using this Chart.

Ex. 1. What is the pressure of equalization when using a standard 8-inch equipment, piston travel being 8-inch? Reservoir volume is 1620 cubic inches.

The vertical line marked 8-inch cylinder diameter intersects the horizontal line marked 8-inch piston travel at A which lies just above the 400 cubic inch cylinder volume line. Following line from A to the 400 cubic inch line, as shown by the dotted line, we find the point B, which represents about 402 cubic inches. From B follow a horizontal line until it intersects the vertical line marked St'd. Cl. (1620 cubic inches) Auxiliary reservoir volume at C. This point lies between the 50 and 55 pound diagonals and would be read as about 52 pounds, which is the pressure of equalization.

Ex. 2. When using a 10-inch cylinder, 8-inch piston travel, what auxiliary reservoir must be used in order to equalize at 52 pounds?

First find, as before, the point of intersection of the 10-inch diameter vertical line with the 8-inch horizontal Piston Travel Line. This gives the point D. Follow, as before, a line from D, parallel to the nearest cylinder volume curve, giving the point E on the left, which represents 628 cubic inches cylinder volume. Follow a horizontal line from E to the 52-pound equalization pressure diagonal, which is not drawn, but would be estimated as shown by the dotted line. This gives the point F. A vertical line from F gives the point G, which represents an auxiliary reservoir volume of about 2,450 cubic inches, requiring a St'd. Cl. 10-inch cylinder auxiliary reservoir. *See note below.*

Ex. 3. When a 14 x 33-inch auxiliary reservoir is used with a 12-inch cylinder, what piston travel will give equalization at 50 pounds?

The vertical line marked 14 x 33-inch auxiliary reservoir intersects the 50-pound cylinder pressure diagonal at H. Following a horizontal line from H, we have the point K, which represents a cylinder volume required of 1,272 cubic inches. Follow a line from K parallel to the nearest curve of cylinder volume, as shown by dotted line, until the 12-inch cylinder diameter vertical is reached, giving the point M. A horizontal from M gives the point N which shows the piston travel required to be about $11\frac{1}{4}$ inches.

NOTE—In finding the necessary size of auxiliary reservoir when the reservoir volume in cubic inches obtained from the chart does not correspond exactly to any standard size of reservoir, that having the next larger capacity should ordinarily be chosen, unless the next smaller reservoir has very nearly the desired capacity.

Rates of Braking

In long runs the rate of braking is of little moment;

in short runs it is an important factor. A high braking rate is very desirable because it permits more coasting in any run resulting in an earlier cut-off, less power consumed and less heating of the motors. A high rate of braking also tends to reduce the size of motor for the given service.

The Energy Consumed in Braking

The amount of energy stored in a moving train, which must be dissipated by the brakes, is sometimes quite large. The kinetic energy of a moving body is represented by the equation $E=\frac{1}{2}M.V.^2$. Where E= the energy expressed in foot pounds, that is the number of pounds raised one foot in one minute. M= the mass of the train (its weight in pounds) or $w \div g$ where g= the acceleration due to gravity which is 32.2 feet per second. V= velocity in feet per second.

Miles per hour $\times 1.47=$ the feet per second.

To absorb this energy and bring a moving train to a stop, it is necessary to exert a force f over a distance d which is expressed as $e=p \times d$ where p= pounds pressure applied to the brakes, d= distance in feet passed over before the speed becomes nil.

If we substitute for m in the preceding equation its equivalent $\frac{w}{g}$ both equations become equal to each other.

Therefore, $D=\frac{w\ v^2}{2\ g\ f.}$

Example:—A 40-ton car must be stopped from a maximum speed of 30 miles per hour on a perfectly straight track. In what distance will it come to a stop if the train resistance due to friction, wind pressure, etc., is 20 pounds per ton and the braking force applied is 280 pounds per ton?

$$D=\frac{40\times2000\times(30\times1.47)}{2\times32.2\times300\times30}=268 \text{ feet.}$$

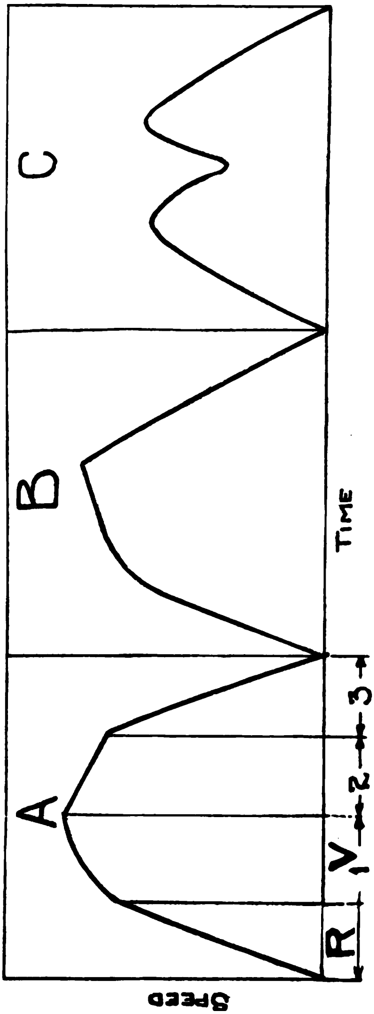


FIG. 67. Elementary Speed Time Curve

The Determination of Train Performance

In electric railway operation it is very desirable to know at any time interval whether a given train is operating at the best efficiency under a given set of conditions. Train performance may be analyzed into the following quantities: distance traveled, speed of train, rate of acceleration, whether positive, zero or negative; power absorbed by the motors and the temperature rise in the armature and field coils of the motor. This information is obtained by means of a train test diagram which is made up of a series of curves termed a distance curve, speed time curve, a current curve, a curve of current squared values; the latter for finding the effective or heating value of the current. In all these curves time is plotted as the abscissae or base line.

Distance Time Curves

A Distance-Time Curve is a curve connecting a series of successive values travelled over in various periods of time. This curve in indicating the performance of a train between stations has a value of nil at the beginning, a gradually rising value as the train gains headway; the shape or slope of the curve being dependent upon the speed of the train, while the maximum value is attained when the train has arrived at the second station; the curve then becoming parallel with the time or base line.

Velocity or Speed-Time Curves

Velocity is the rate of change of position of a body. Speed is generally stated in miles per hour; a speed of one mile being equivalent to a distance travelled of 1.47 ft. per second. The quantities, distance or space s, time t, and velocity, V. bear the following relations to each other:— $V=s \div t$.

An elementary speed-time curve consists of three distinctive parts. In the diagram (Figure 67 part A) power is applied to the car motors in section (1) or what

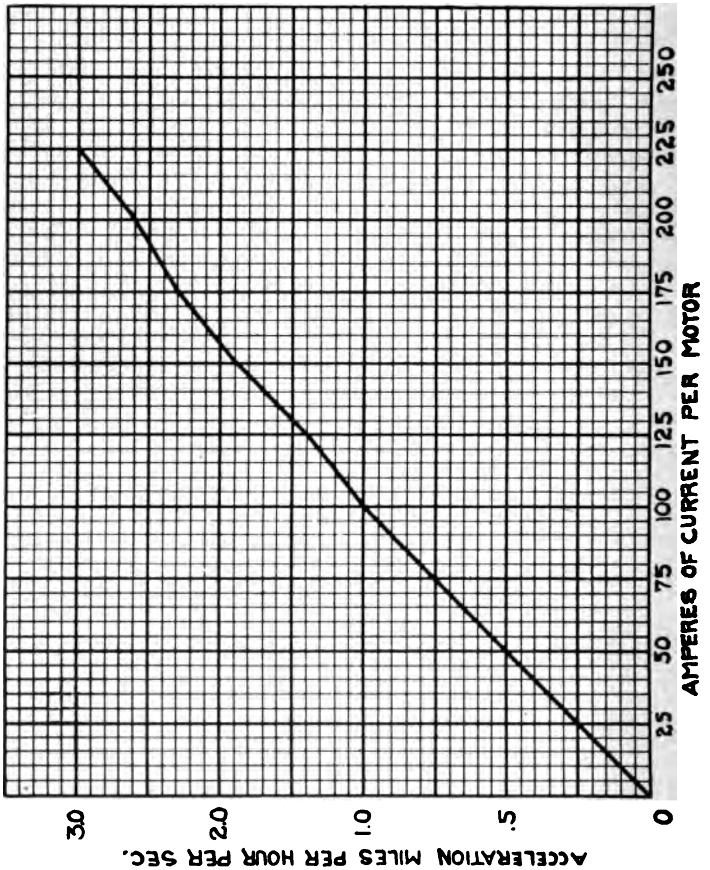


Fig. 68. Motor Acceleration Curve

is termed the acceleration portion; in section (2) power is shut off, the train motion being due to its own inertia, in section (3) the brakes are applied termed "braking portion" and the speed is quickly reduced. The acceleration section may be analyzed into two parts R. and V. Part R shows the acceleration while resistance is in series with the motors. Part V. is the time during which the line voltage is impressed directly on the motors. The effect of grades and curves may be such that several applications of power will be required, producing a "peaked" curve made up of several parts, (Part C. Figure 67). When a car or train is to be operated at maximum speed for a given distance the speed time curve will be composed of two parts, acceleration and braking, no coasting occurring Part B.

Speed-time curves serve two valuable purposes: (1). They determine a desirable schedule to be made over a road of known percentages of grade and contour when a maximum speed, a given rate of acceleration and braking are assumed with a definite number of applications of power to a specific motor equipment. A speed time curve or number of such curves giving a complete schedule for a day enables one to derive other curves from the best of which a type of motor can be selected which will operate on a chosen schedule without overheating. (2). From the characteristic curves of a certain motor showing its behavior when driving a car, the speed-time curve may be plotted and referred to a definite set of conditions (grades and curves) between stations.

Motor Acceleration Curves

Acceleration is the rate of change of velocity. The unit of acceleration is the mile per hour per second (abbreviated: M.P.H. per S.) An acceleration of one mile per hour per second is equivalent to,

$$\frac{5280 \text{ (feet in one mile)}}{3600 \text{ (seconds in one hour)}} = 1.47$$

feet per second, or the distance traveled per second by a train going one mile per hour.

The rate of acceleration common in electric railway practice varies from one-half a mile up to two miles per hour per second. The former figure applying to service in congested centers of population and the latter to high-speed interurban service.

On a run of unlimited length a car will attain the same running speed irrespective of the initial acceleration but with the lower rate of acceleration some time will elapse and a greater distance will be traversed before this maximum speed is attained than would be the case with high initial acceleration. The lower the acceleration, the less will be the distance traversed in a given time; therefore to maintain a given schedule, a low acceleration necessitates having power on the motors for a greater portion of the time and less coasting is possible than with a higher rate of acceleration; the brakes must also be applied when running at higher rates of speed. The voltage lost in the rheostats depends on the rate of acceleration and is greater with low accelerations.

Acceleration is produced by applying a certain force. A constant force applied, as for instance, a constant current on the terminals of a car motor will result in a constant acceleration.

Tractive Effort

The force transmitted through the gearing from the armature shaft of a motor to the base of the car wheels produces a horizontal pulling action called tractive effort. The tractive co-efficient is expressed as the ratio between the weight on the driving wheels and the tractive effort; its value depends largely upon the condition of the tracks. A table of tractive co-efficients has been given on page 93. Tractive effort is frequently termed draw bar pull and has a definite relation to torque or turning effort of a motor.

Relation Between Torque and Power

The power developed by an electric motor depends on both the torque and speed and is proportional to their

product. By torque is meant the pounds pull at one foot radius from the center of the armature shaft. Power is the rate of using torque. The relation can be illustrated by supposing a cable wound on a drum two feet in diameter and used to hoist a load without the medium of intermediate pulleys; the tension in the cable corresponds to the torque. If the tension is 500 pounds and the speed is 200 feet per minute, work is being done at the rate of 500×200=100,000 foot pounds, or 3.03 H.P.

The quantities, mass, acceleration and force have the following relation to each other: Force = Mass × acceleration. Since the equivalent of Mass is—

$\frac{w}{g}=\frac{w}{32.2}$ we have $A=\frac{F\times 32.2}{w}$ in which A=acceleration in feet per second per second F.=the tractive effort or force applied in pounds.

Expressing the acceleration in miles per hour per second we obtain $a=\frac{A}{1.47}=\frac{32.2}{w\times 1.47}=\frac{32.2\ F}{w\times 1.47}$

Calling W. the weight in tons= $\frac{w}{2000}$ then

$$a=\frac{32.2}{W.\times 1.47\times 2000}$$ or reduced to simpler form $=\frac{F.}{91.3\ W}$ which shows that 91.3 pounds tractive effort will accelerate one ton at the rate of one mile per hour per second. Reducing this equation to its simplest form, $\frac{F}{91.3\ W}=\frac{.01096\ F}{W}$

A motor acceleration curve is a curve showing the value of acceleration of a given motor with different inputs or current (See Figure 69). To plot a motor acceleration curve the complete weight of the train must be known, including trucks, motors, controlling apparatus and brake equipment; also the number of motors per car.

This information enables one to find the gross tons pulled by each motor. The amount of acceleration for

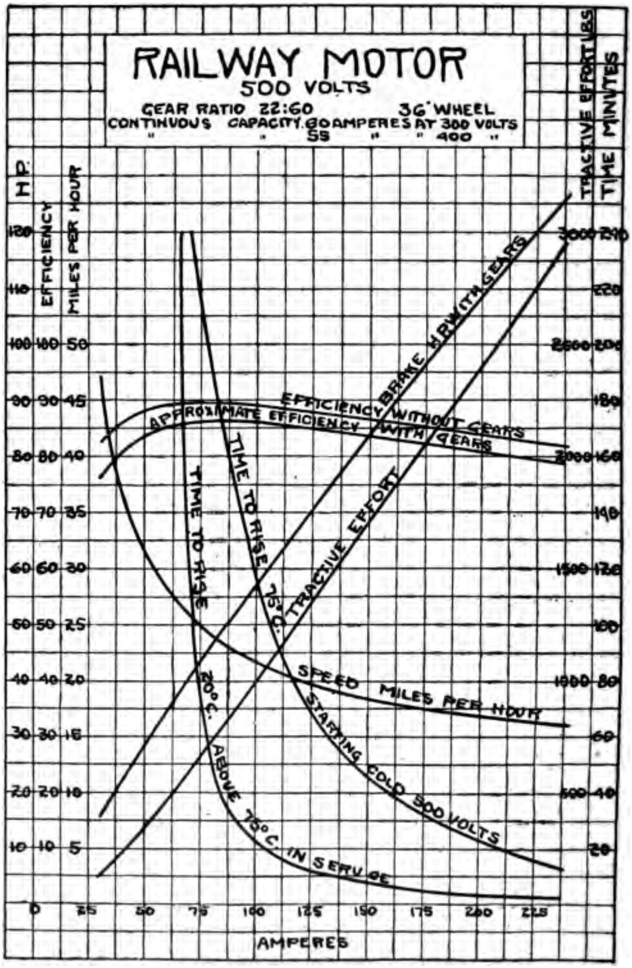


FIG. 69. Tractive Effort Curve

the tractive effort per ton is then found for various current inputs and a curve of acceleration and current plotted.

For instance, assume a car weighing 40 tons loaded, equipped with four motors, the characteristic curves of which are shown in Figure 69. Each motor will accelerate 10 tons. Reference to the tractive effort curve of the motor will show that a current input of 125 amperes will produce a tractive effort of 1350 pounds or approximately 141 pounds per ton which is equivalent from the acceleration equation given, to 1.41 miles per hour per second. In like manner acceleration values are obtained for various other current inputs and a curve plotted showing the motor acceleration for a particular equipment. Such curves are greatly influenced by the particular profile of a road, such as grades and curves; and also by train resistance.

Train Resistance

Train resistance is a variable quantity and very difficult to determine. For any given run the energy expended in overcoming train resistance is constant. That consumed in braking depends on the rate of braking and the car speed when the brakes are applied. Train resistance is affected by the weight, size and shape of the car, speed, condition of track, wheels, motor and axle bearings. It has three component parts, viz: journal friction, rolling friction and wind resistance. Journal friction is practically independent of the speed; rolling friction is inversely proportional to speed; wind resistance is proportional to some power or speed not yet determined. A constant value of 20 pounds per ton is taken for general operation of cars at low speeds.

The Formula of Blood for Train Resistance gives very close results in practice. This formula is:

$$R = A + B\,M + \frac{(C + D)}{T}\,M^{1.8}$$

Where R = train resistance in pounds per ton, $A = 5.0$, $B = 0.12$, $C = 0.0014$, $D = 0.35$, M = miles per hour and

T = weight of car in tons. Where not more than two trailers are handled by a motor car, the train resistance for trailers may be taken as:—

12 pounds per ton from 0 to 50 M.P.H.
13 pounds per ton from 50 to 60 M.P.H.
14 pounds per ton from 60 to 70 M.P.H.

Table of Train Resistance Values

The following table of train resistance values for various speeds and weights of cars is based on Blood's formula.

POUNDS PER TON FOR CARS OF VARIOUS WEIGHTS

Miles per Hour	20 Tons	25 Tons	30 Tons	35 Tons	40 Tons	45 Tons
25	11	11	12	12	13	14
30	13	13	14	15	16	17
35	15	15	16	17	19	20
40	17	18	19	20	22	23
45	19	20	21	23	25	27
50	21	23	24	26	28	31
55	24	25	27	29	32	35
60	27	28	30	33		
65	30	31	34	37		
70	33	35	37	41		
75	36	38	41	45		

Effect of Curvature in Track

Curves offer a resistance to motion of a train because turning a curve is equivalent to revolving around the center of curvature; with reference to this point a centrifugal force exists due to the tendency of the car to travel in a straight line. This force is balanced by the pressure of the outer rail against the flanges of the wheel. This results in friction between flanges and rails which does not exist when running on a straight track. The coefficient of friction has never been satisfactorily determined but must be greater than usual on account of the

tendency of the flanges to bite into the rails and also because of the slipping of one of each pair of wheels on the same axle due to the difference in length of the outer and inner rails. Curve resistance may be taken at from .4 to .8 pounds per ton per degree of curvature.

Influence of Grades

A grade is defined as the percentage rise in altitude in 100 feet of track; thus a grade of 1% means an increase of one foot in height in 100 feet horizontal distance. Grades exercise a negative effect on motor acceleration equal to $\frac{1}{100}$ and so on, of the train weight.

A grade of 1% has a negative effect of 20 pounds per ton, a grade of 2%, 40 pounds, etc.

For a total tractive effort there must be added the tractive effort due to curves, train resistance and the rolling friction on the level. When traveling up a grade the net tractive effort of a car or train is reduced by the amount of grade resistance.

Train Acceleration

The actual acceleration of a car or train after considering the influence of grades, curves and train resistance is found by the following equations:

$A = .01096\ (e - g - r + h)$ for up grades.

$A = .01096\ (e - g - r - h)$ for down grades; in which

A = acceleration in miles per hour per second.

g = equivalent traction due to curves in pounds per ton = 0.4 to 0.8 pounds per ton per degree curvature.

r = equivalent traction due to train resistance in pounds per ton.

h = equivalent traction due to grades in pounds per ton.

.01096 = acceleration co-efficient. (See page 113).

e = tractive effort per ton per motor — stated in pounds per ton.

To illustrate the application of these two formulae, assume a 40-ton car equipped with two motors pulling a 2% grade and a 1% curve at a speed of 20 miles per hour, and that a current of such value as will exert a tractive force of 3,000 pounds on each motor is passing through them.

The tractive effort per ton $= \frac{3000 \text{ lbs.}}{20 \text{ tons}} = 150$ lbs.

The tractive effort per ton = ...	+ 150	pounds
The traction due to up grades per ton =	– 40	pounds
Traction r due to train resistance = ...	– 13	pounds
Traction g due to curves per ton (factor .6) = ...	– 1.2	pounds
Total train traction = ...	95.8	pounds

Acceleration a = .01096 × 95.8 pounds = 1.15 M.P.H. per second.

Or given these conditions the train will accelerate at the rate of 1.15 miles per hour per second.

Negative Acceleration or Deceleration

The opposite of acceleration is termed deceleration and is caused by grades, curves, train resistance and also by application of the brakes. The net train acceleration may be obtained by deducting the total deceleration caused by these effects from the motor acceleration.

The deceleration caused by braking, a, may be found from the equation:

$$A = .01096 \, (M - g - r \pm h)$$

where a = deceleration

M = braking force in pounds

g = equivalent traction due to curves in pounds per ton = 0.4 to 0.8 pounds per ton per degree curvature

r = equivalent traction due to train resistance in lbs.

h = equivalent traction due to grades (whether up or down grades) in pounds per ton.

Messrs. Ashe & Keiley (Electric Railways, D. Van Nostrand Company, Publishers, New York) give the

following equation for determining the total time from brake signal to stop from a given speed at brake signal:

$$t = \frac{T + S - 0.16\ T}{R}$$

where t = time in seconds from brake signal to stop
T = time from brake signal to setting of shoe
S = speed at brake signal
R = rate of braking in miles per hour per second from setting of shoes to stop.

The co-efficient of retardation 0.16 was determined from several coasting runs to be the retardation due to friction and wind resistance, or approximately 0.16 miles per hour per second within the range at which tests were made.

Method of Plotting Speed Time Curves

To lay out a speed time curve it is necessary to have the following information: A general contour of the road, that is, grades and curves.

The characteristic curves of the motor desired and operating at rated voltage; this information is usually supplied by the manufacturer.

The total weight per car including trucks, motors, controlling and braking apparatus and live load.

The number of motors per car.

The rate of acceleration and the rate of braking.

The maximum speed desirable and the proposed schedule speed between stations.

Data

Weight of car including all equipment and "live load" = 45 tons: four motors per car.

Track layout: First 500 feet level and straight; second 1000 feet up grade of 1%; remainder of run level and straight.

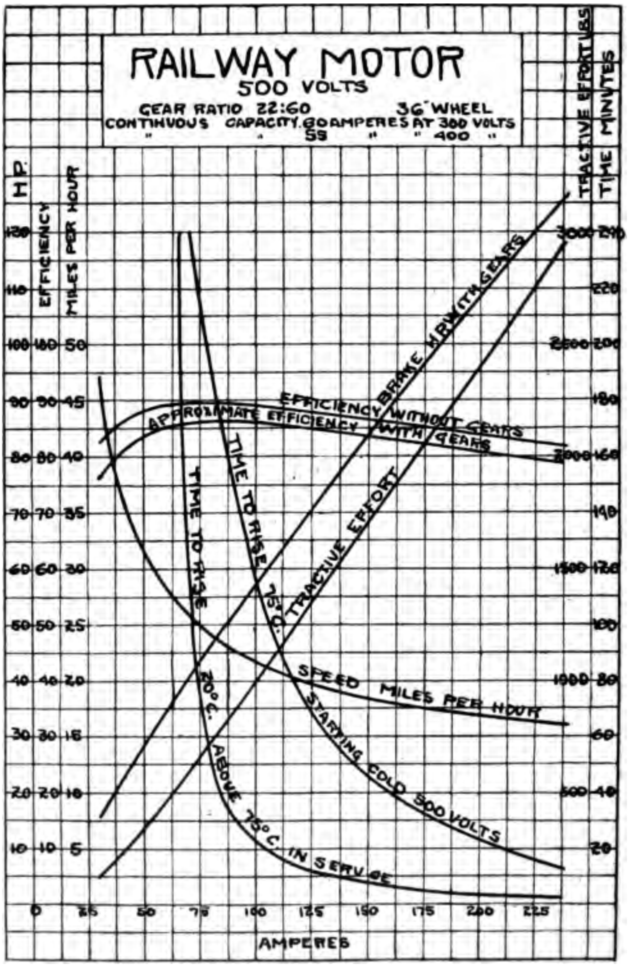


FIG. 70. Characteristic Curves of Railway Motor

Train resistance from Table page 116.
Trolley voltage 500.
Length of run one mile.
Length of stop 12 seconds.
Schedule speed 25 miles per hour.
Initial acceleration 1.7 M.P.H. per S.
Braking rate 1.7 M.P.H. per S.
Characteristic curves of motor as shown in Figure 70.

Since 100 pounds per ton produces an acceleration of 1 M.P.H. per S. the net tractive effort is $1.7 \times 100 \times 45 = 7650$ pounds. At 18 M.P.H. the train resistance (per Blood's formula) is $10 \times 45 = 450$ pounds, total tractive effort produced by the motors in starting must therefore be $7650 + 450$ pounds $= 8100$ pounds or approximately 2025 pounds per motor. Referring to the motor curves it will be seen that the necessary tractive effort is produced when each motor is taking 170 amperes. The speed corresponding to this input is 18 M.P.H. Therefore the car may be accelerated at the rate of 1.7 M.P.H. until this speed is reached, when the full line voltage is applied to the train. The time required to come from rest to a speed of 18 miles per hour with acceleration of 1.7 M.P.H. per S. is $\frac{18}{1.7} = 10.6$ seconds (about). Hence at the end of 10.6 seconds from the time current is applied the car will have attained a speed of 18 M.P.H. the motors will be in parallel and running on the motor curve at 500 volts. As the car speed goes beyond this value the current decreases and likewise the tractive effort. (See Figure 70). So the rate of acceleration no longer remains constant but decreases, and speed of car will increase at lower rate. Increase of speed also causes train resistance to increase and still further reduce the initial acceleration value.

The method of procedure in determining other points in the speed time curve is as follows:

At a speed of 19 M.P.H. the current will have dropped to 137.5 amperes and the tractive effort per motor will then be 1525 pounds. The train resistance will then be

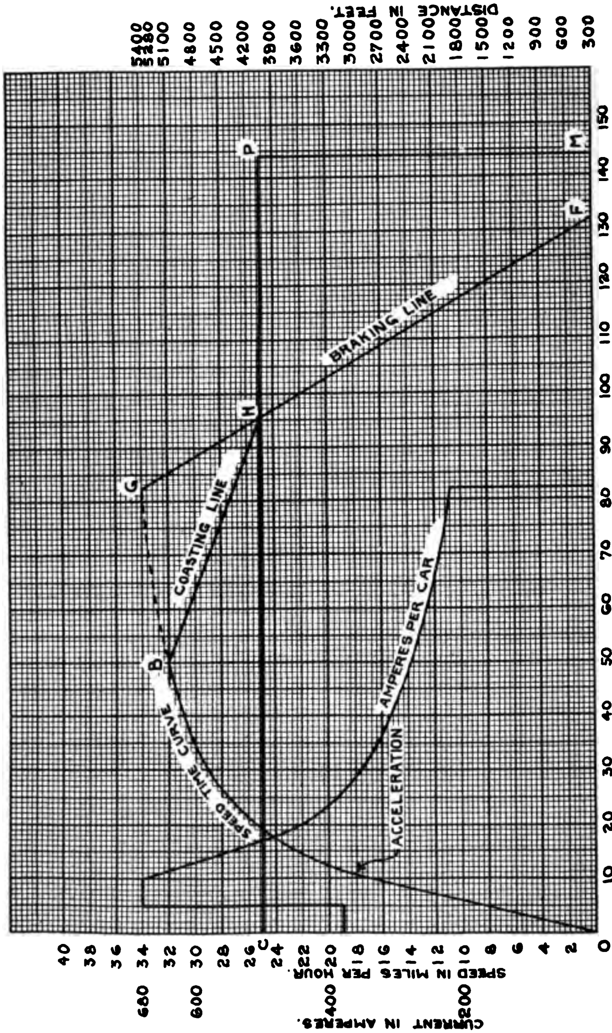


FIG. 71. A Calculated Speed Time Curve

$10.5 \times 45 + 20 \times 45 = 1372.5$ pounds or 343.1 pounds per motor. The net tractive effort will be $1525 - 343.1 = 1181.9$ pounds per motor and the rate of acceleration will be 1.18 M.P.H. per S. $\frac{1181.9.}{100}$ Since the tractive effort and acceleration increases gradually while the car is speeding up from 18 to 19 M.P.H., the assumption may be made without appreciable error that the average acceleration during this period is the average of the initial and final acceleration, that is the average acceleration between 18 and 19 M.P.H. is $\frac{1.7 + 1.18}{2} = 1.44$ M.P.H. per S. To increase in speed from 18 to 19 M.P.H. or a difference of 1 M.P.H. at the rate of 1.44 M.P.H. per S. requires $\frac{1}{1.44} = 0.69$ seconds; therefore the car reaches a speed of 19 miles per hour in $10.6 + 0.69 = 11.29$ seconds from the start. This is the second point on the speed time curve. At 20 miles per hour the current input is 123 amperes. The tractive effort is 1325 pounds per motor. The train resistance is $12 \times 45 \div 4 = 135$ pounds per motor. The net tractive effort is $1325 - 135 = 1190$ pounds per motor. The rate of acceleration at 20 M.P.H. is 1.19 M.P.H. per S., the average acceleration being $1.18 + 1.19 \div 2 = 1.18$ M.P.H. per S. The time to increase one mile per hour is $\frac{1}{1.18} = 0.84$ seconds. The car will therefore reach a speed of 20 M.P.H. in $11.29 + 0.84 = 12.13$ seconds. This is the third point on the speed time curve.

This process of determining points may be continued until the curve becomes a straight line, when the tractive effort will be equal to the train resistance.

The speed-time curve shown in Figure 71 is plotted from the calculated data which is very conveniently tabulated as follows:

45-TON CAR. 4 MOTORS

Miles per Hour	Pounds Tractive Effort	Pounds Train Res'st'ce	Net Tractive Effort	Rate of Accelera. M.P.H. per Sec.	Time in Seconds	Current Input Amperes
18	2025	112.5	1912.5	1.91	10.6	170
19	1525	343.1	1181.9	1.18	11.29	137.5
20	1325	135	1190.0	1.19	12.13	123.0
22	969	140.6	828.4	.828	14.12	95.0
24	695	151.8	543.2	.543	17.24	80.0
26	625	164.2	460.8	.460	20.34	72.5
28	450	177.7	272.3	.272	25.80	60.0
30	375	191.2	183.8	.183	34.64	54.0
32	300	204.7	95.3	.095	49.13	48.0
34	250	220.5	29.5	.029	81.38	43.0
36	200					

As the car is to make a run of one mile at a speed of 25 miles per hour, the time required to make a run is $\frac{3600}{25} = 144$ seconds. This time includes a 12-second stop so that the actual distance is to be covered in 132 seconds. The specifications require a braking rate of 1.7 M.P.H. per S. Starting from the 132 second point on the base line, the braking line will be run through the 20.4 M.P.H. point, cutting the speed curve at G. O.B.G. is the curve with power on. G.F. is the brake line drawn from F. F.M. is the 12-second stop. The area enclosed in the speed time curve is a measure of the distance travelled by the car; for instance: suppose the car runs at 15 miles per hour for 30 seconds, it will cover $\frac{15 \times 20}{3600} = \frac{1}{12}$ mile.

Likewise if the run is made at 20 miles per hour for 60 seconds, the distance travelled will be $\frac{1}{6}$ mile. It is thus obvious that one cross section square (Figure 71) represents $\frac{1}{12}$ of a mile on the speed time curve; for a mile run should enclose an area equal to exactly 12 squares in the figure. If the car could be started instantly and brought up to a speed of 25 miles per hour and run at

this speed for one hundred and forty four seconds and then instantly stopped, the speed time curve would be the rectangle O.C.P.M. In order that the curve O.B. H.F.M. should accurately represent a mile run its area should be equal to that of the rectangle above, or 12 squares. The power part of the curve, the stopping portion and the braking rate are fixed. The only variable part to get the correct area is the coasting line B.H. The slope of the coasting line is determined as follows:

Since train resistance is variable, the coasting line is a curve, the slope of which becomes nearly horizontal for low speeds. A trial or tentative position of the coasting curve is drawn in and the enclosed area measured by a planimeter. If this area is too small the coasting line is shifted upwards, the slope being kept constant and if the area is too great, the coasting line is dropped down a trifle. This cut and try move is carried on until the area is found to be correct.

If, with the highest practicable rate of acceleration and no coasting line, the enclosed area is found too small the equipment is insufficient to maintain the required schedule; either larger motors must be used or else the same motors with higher gearing.

Plotting Current and Power Curves

These curves may be plotted directly from the speed time curve. The characteristic curves of the motor show that with any definite impressed voltage, a definite speed value always corresponds to a definite current value; hence when all resistance is cut out, the plotting of the current curve is readily done by taking at any instant, the current value corresponding to the speed at that time. With the controller full on the motors are connected in parallel so that the current as indicated by the characteristic curve must be multiplied by the number of motors on the car to give the current per motor.

On starting both motors are in series—assuming a two-motor equipment. With four motors per car there

are two sets of two motors each, the motors of each group being connected in parallel and the two groups in series. From the instant of starting until the controller connects the motors in parallel, the current taken by each car equals the current per motor times one-half the number of motors on a car. In this case the current required to produce an acceleration of 1.7 M.P.H. per S. is 170 amperes. The motors will hence consume 340 amperes when running in series and 680 amperes when running in parallel.

From the parallel position on the curve, the current input at successive speeds may be plotted by reference to the speed-current curve of the motor.

For a complete and thorough discussion of the method of plotting speed time curves and the analysis of train motion in general the reader is referred to the following treatises:

Notes on the Plotting of Speed-time Curves-Mailloux. Proceedings American Institute of Electrical Engineers, vol. 19, page 901. Reprinted in Street Railway Journal, July 5, 1902, July 26, 1902, Aug. 9, 1902, Aug. 16, 1902, Aug. 23, 1902, Aug. 30, 1902.

Electric Railways—Ashe & Keiley, D. Van Nostrand Company, Publishers, New York City.

Electric Railway Engineering—Wynne. Electric Journal, Pittsburg, Pa., Serial, January-August, 1906.

Railroad Car Braking—Parke. Transactions American Institute Electrical Engineers, vol. 20, page 235. Some Brake Tests and Deductions Therefrom—Keiley, Transactions American Institute Electrical Engineers, vol. 20, page 219.

Train Resistance Formulae—Blood. Street Railway Journal, July 5, 1902.

What is Meant by a Grade Stated in Per Cent?—Hering. Street Railway Journal, July 19, 1902.

A Graphical Method of Making Time-Speed Curves—Valentine. Street Railway Journal, Sept. 6, 1902.

The reader is referred to the following good books for *information* on the generation and distribution of power

for electric railways and the financial side of electric railway operation:

Electrical Transmission of Energy—Abbott. (D. Van Nostrand Co., N. Y.)

Long-Distance Electric Power Transmission—Hutchinson. (D. Van Nostrand Co., N. Y.)

Power Distribution for Electric Railways—Bell. (McGraw Publishing Co., N. Y.)

Electric Railway Economics—Gotshall. (McGraw Publishing Co., N. Y.)

Engineering Preliminaries for Interurban Railways—Gonzenbach. (McGraw Publishing Co., N. Y.)

National Portable Air Compressor Outfits

The rapidly increasing applications of compressed air in industrial manufacturing plants, in private institutions, power plants and car barns has given quite an impetus to the manufacture of electrically driven air compressors which are self-contained and conveniently taken to the place where the compressed air is utilized. Such outfits dispense with the necessity of installing an expensive central air compressing plant and long lines of piping in those instances where only moderate amounts of air are required intermittently.

The extreme simplicity, flexibility, cleanliness and reliability of air as a source of power in the repair shop for such work as drilling, riveting, chipping of metals, etc., cannot be surpassed. In car barns of electric railway companies air is highly convenient and effectual as a means of thoroughly freeing armature coils and all parts of the electrical apparatus and car from dirt and dust. In power houses and sub-stations compressed air offers many advantages in the way of convenience, adaptability and thoroughness for blowing out dust from generator coils, field magnets and commutators, etc. In automobile garages the use of compressed air is especially advantageous as the most convenient, quickest and easiest method of inflating tires, cleaning dust from every nook and cranny of cushions, upholstered seats, running gear, etc.

General Description

National Portable Compressor Outfits are made up of standard apparatus throughout such as has been described in the pages of this Instruction Book, each part of which has been thoroughly tried out in air-brake service—which is the most severe service in which it could be used.

The outfit comprises the new improved National compressor, an automatic Type "N" governor and necessary piping, an air gauge and reservoirs, a combined switch

and fuse and a hose-pan sufficiently large to contain from 75 to 100 feet of hose, the whole being mounted on a substantial angle iron frame supported on wheels. The front wheel is hung in a pivoted fork made of cast steel, the outfit being drawn around by means of a wrought iron tongue.

FIG 72. National Portable Outfit with A-1 Compressor.

One of the greatest advantages in the design of National portable air compressors is the exceptionally small width of the outfit which is gained by such a disposition of the parts that there is no waste of space on the truck. The width of the outfit over all is but 29¾ inches, which readily permits it to be taken through doors and openings in shops and factories of much smaller size than the average. In crowded mills and factories the National portable air-compressor outfits may be easily taken through spaces where other types of such apparatus would be wholly

impracticable. National Portable Outfits are made in sizes of from 11 to 50 cu. ft. of free air per minute.

Type "L" Waterjacketed Stationary Compressors

These compressors are identical in every respect with the compressors described in preceding chapters, except that provision is made for a circulation of water around the cylinders and heads, keeping these parts at a minimum temperature and permitting the machines to be operated continuously.

All working parts of the compressor operate in a bath of oil. The other parts are automatically and continuously lubricated in a most thorough manner.

With the waterjacketed type there is furnished a water governor which automatically cuts off the circulation of water as soon as the compressor is shut down. These governors are very simple and reliable in operation and eliminate the possible neglect to turn the water off after stopping the machine, and in a like manner the water is admitted to the cylinders and heads when the compressor is started up.

Although all the working parts of the machine are entirely enclosed and protected from injury, accessibility was carefully considered in the design and every part can be quickly and easily inspected.

Motor-driven compressors meet a large demand as there are many places where electric power can be more conveniently used than any other. The compressor can be operated from a lighting, power or railway circuit.

For detail description of Portable Outfits and Type L Compressors write for Bulletin 374.

Fig 73. Type "L" Water Jacketed Compressor

National A. C. D. C. Air Brake Apparatus

The advent of the single phase electric railway system, and the adoption by numerous electrified sections of existing steam railroads of single phase alternating current as motive power, has necessitated radical changes from former standards in the car and other equipment, including the air brake apparatus—more specifically the motor compressor and the governor for same.

The present tendency toward operating the interurban lines on single phase circuits and running the cars into the heart of the city over the direct current city lines necessitates the building of apparatus of such design and construction as permits of its operation on both the direct and alternating current circuits. The fundamental characteristics to be taken into consideration in designing single phase air brake apparatus are high efficiency, serviceability, and absolute reliability and freedom from breakdown at all times. To meet the exacting conditions of service required by modern high speed single phase electric railway operation the National Brake & Electric Company has developed and perfected a class of apparatus that compares most favorably in all respects with its well known direct current air brake equipment.

The Compressor

The A. C. D. C. type of motor compressor manufactured by this Company is the result of years of serious study, careful experimental work and a thorough and intimate knowledge of the conditions and requirements of the electric railway braking art in its present day state of perfection.

The compressor, in general appearance, resembles closely the Company's standard direct current machine, and is also of the entirely closed type as may be seen by referring to Figure 74. The motor and compressor are

two distinct and separate units, and either one may be replaced without in any way interfering with the operation of the other. The compressor proper is of exactly the same design and construction as that described in pages 23 to 25 of this book, and the instructions for inspection and maintenance on pages 14 to 20 (such as relate to the compressor and not to the motor) also apply to it.

Fig. 74. A. C. D. C. Compressor. Type BB-2

The capacity of this type of compressor is 25 cubic feet of free air per minute.

The Motor

The motor is of the four-pole commutator type with two consequent poles, and is designed for operation on voltages ranging from 500 to 600 volts direct current circuits, and on voltages ranging from 280 to 340 volts

alternating current 25 cycle single phase circuits. The motor has two distinct field windings, one for alternating current and one for direct current. Laminated sheet steel pole pieces are used. The pole faces are provided with a compensating winding, which consists of four separate coils, which are short-circuited upon themselves. The motor frame consists of three parts, the motor base, the magnet frame and the motor cover. The motor cover is bolted to both the magnet frame and motor base. The magnet frame is bolted to the motor base and held in position by four cap screws, and is adjusted centrally with the armature, in regards to its vertical height, by means of shims, and laterally by means of adjusting set screws.

The armature is removed by taking off the motor cover, then removing the bearing cap and cap screws holding the magnet frame to the motor base, and then lifting the magnet frame and armature away from the base. The armature can then be taken out of the magnet frame with ease. Figure 75 shows the compressor partly dismantled, and shows the armature removed from the magnet frame.

The field coils are removed by first removing the armature and then taking out the four cap screws that hold the pole piece onto the magnet frame. The pole piece can then be pushed in towards the center line of the shaft far enough so that the field coil can be removed. This can be done without disconnecting the compensating winding, as the latter is flexible and can be bent as the pole is pushed inward or back into place. So long as the adjusting shims and set screws are not disturbed the magnet frame can be put back into its original position without any further adjustment.

The commutator is of high commercial quality hard-drawn lake copper, well proportioned and well insulated, with a liberal wearing depth and is designed for severe service.

The brush gear is of the same distinctive construction

as that used on the National direct current compressors, and differs from same mainly in the manner of fastening and the number of brushes. The brush gear proper is securely fastened to a cast iron yoke made in two halves, which is secured in a groove running entirely around a projection of the armature bearing at the commutator end of the motor. Two sets of brush holders of two brushes each are used.

FIG. 75. A. C. D. C. Compressor Partly Dismantled

The holders are fitted with an improved spring tension device which is constant over a very wide range of variation and capable of an easy and correct adjustment. The very liberal insulation of this brush gear gives it a maximum protection against insulation troubles, as may be seen by the fact that the external leakage surface of same is $1\frac{1}{4}''$, as compared with the $\frac{3}{8}''$ or $\frac{1}{2}''$ usually found in other makes of compressors.

The inspection of the armature, commutator and brushes is rendered an easy and quick process by means of the inspection doors at the sides of the motor casing.

Method of Starting Compressor

The compressor is started by throwing it directly on the full voltage, either alternating current or direct current. A relay is provided for automatically making the connections for running the motor either on alternating or direct current circuits, and is shown in Figures 76 and 77. When the direct current circuit is closed the necessary

FIG. 76. Relay Complete

connections for direct current operation are made by the solenoids of the relay attracting plungers to which are secured the contact pieces. When operating on the alternating current circuit these solenoids are not in circuit and the contact carrier drops by its own weight and makes the necessary connections for operating on alternating current. The relay is entirely enclosed and is, therefore, *protected* from the elements. A diagram of connections

is supplied with each compressor and relay, and the leads are all tagged so that no wrong connections need be made.

Method of Suspension

The compressor is suspended in a cradle under the car body in the same manner as shown in Figure 4, page 11. This method of suspension allows the entire pump to be exposed to the cooling effect of the air at all times, and none of the parts of the suspension cradle obstruct the access to all parts of the compressor. The relay is mounted under the car body with the compressor.

FIG. 77. Relay Without Cover

Further information in regards to this type of apparatus will be furnished upon request.

The standard type "N" Oil Pneumatic Governor is furnished in connection with National A. C. D. C. Air Brake Equipments, and will operate equally as well on either direct or alternating current circuits. A detailed description of the Type "N" Governor will be found in the instruction chapters of this book on pages 37 to 43 inclusive.

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